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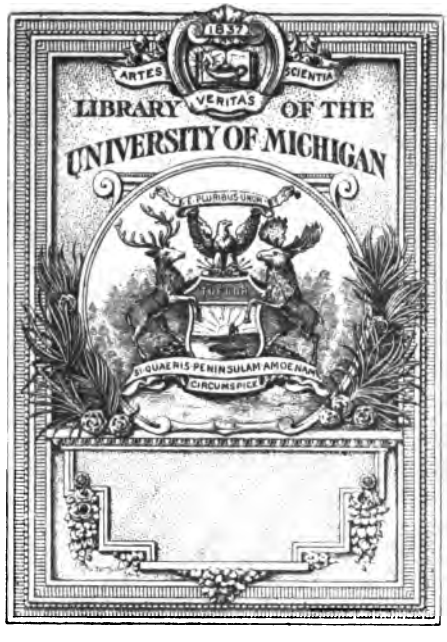
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Issued December 9, 1911.

U. S. DEPARTMENT OF AGRICULTURE,
FOREST SERVICE—Circular 191.
HENRY S. GRAVES, Forester.

FOREST PRODUCTS LABORATORY SERIES.

MODIFICATION OF THE SULPHONATION TEST FOR CREOSOTE.

BY

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WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1911.

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MODIFICATION OF THE SULPHONATION TEST FOR CREOSOTE.

A NEW SULPHONATION TEST.[1]

The sulphonation test described in Forest Service Circular 112 has been found to give erratic results at different times and in the hands of different operators. The method was also rather long and tedious, making it altogether an unsatisfactory test. Since the publication of the method the conditions of the test have been made more specific, the time required has been shortened, the procedure has been made simpler, and the accuracy has been increased so as to give concordant reading in the hands of different operators. The significance of the test, described in Circular 112, is as follows:

In contradistinction to the hydrocarbons of the paraffin series, those of the aromatic series react with concentrated sulphuric acid with marked ease. The products of this reaction, in which a sulpho group or groups replace hydrogen in the aromatic compound, are called sulphonic acids and the process is known as sulphonation. For example, the reaction with benzene would be $C_6H_6+H_2SO_4=C_6H_5SO_3H+H_2O$. The sulphonic acids are characterized by their solubility in water. If a fraction from the distillation of a creosote oil be treated under proper conditions with concentrated sulphuric acid, it will be converted into a mixture of sulphonic acids, which will readily dissolve in water. If, however, there are paraffin bodies present they will not be attacked to the same degree as the aromatic hydrocarbons, and when the products of the sulphonation are treated with water the paraffin components will remain as a residual oil. In applying this test to creosote oils it has been found that the most information is obtained by using it on the higher boiling fractions.

EXPERIMENTAL PART.

In a general way the sulphonation test may be divided into two stages: (1) The treating of the material with sulphuric acid, and (2) the separation of the unsulphonated residue from the reaction mixture. The first affects the accuracy of the test and the time required, while the second chiefly affects the time.

EXPERIMENTS WITH DIFFERENT STRENGTHS OF ACID.

Experiments were carried out with different strengths of acid, acting for different lengths of time. The strengths of acid used

[1] The general method used in making this test is similar to that recommended in Bureau of Chemistry Bulletin 135 for the detection of mineral oils in turpentines, but several modifications have been made in order to obtain conditions more suitable for use with creosote.

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were ordinarily concentrated sulphuric (95 per cent H_2SO_4), 36 times normal sulphuric (96 per cent H_2SO_4), and 37, 38, and 39 times normal. With these different strength acids acting for different lengths of time the same numerical results were obtained under the following conditions:

1. 50 cc of ordinary acid reacting upon 10 cc of the creosote fraction for 17 hours at 98°.

2. 40 cc of 36 times normal acid acting upon 10 cc of creosote fraction for 3 hours at 98°.

3. 40 cc of 37 times normal acid acting upon 10 cc of creosote fraction for 1 hour at 98°.

4. 25 cc of 38 times normal acid acting upon 10 cc of creosote fraction without standing after the more vigorous reaction has ceased. (In all cases the acid was added to the creosote about 10 cc at a time, and the mixture was shaken for two minutes after each addition of acid.)

Of the four conditions the last is very difficult to control because of the extreme energy of the acid. This is shown by the fact that the temperature of the reaction mixture rose to over 100° C. within one minute after the addition of the acid to the creosote fraction. There is also a tendency of this acid to yield erratic results because the sulphonic acids formed by the reaction of the sulphuric acid on the creosote seem to include minute particles of unsulphonated oil, making it very difficult to effect a complete separation of the unsulphonated residue. The 39 times normal acid acted similarly to the 38 times normal, only the residue was even more difficult to separate. Of the first three methods the one best suited to the purpose of this test is the third, since it gives in the shortest time a residue which can be easily separated.

EXPERIMENTS WITH METHODS OF SEPARATING RESIDUE.

Experiments were carried out with different methods of separating the unsulphonated oils from the reaction mixture to determine if any difference could be obtained by using various methods of procedure. The three methods used were:

1. The reaction mixture after treatment was transferred to a separating funnel having a long graduated neck. The funnel was filled with acid and allowed to stand several hours until a constant reading of the volume of unsulphonated oil was obtained.

2. The reaction mixture after cooling was poured into a large volume of water. The unsulphonated oil which floated on the surface was collected and measured in a graduated cylinder.

3. The reaction was carried out in a Babcock milk bottle which after the completion of the reaction was cooled, filled to the top, and whirled in a Babcock centrifuge.

The readings on two oils treated in the same manner and with the same quantity of sulphuric acid, but with the sulphonation residue separated by different methods, are given in Table I.

TABLE I.—*Sulphonation residues obtained by different methods of separation.*

Sample—	Amount of unsulphonated oil.		
	Method No. 1.	Method No. 2.	Method No. 3.
	cc.	cc.	cc.
No. 1	0.9	0.9	0.88
No. 2	.6	.6	.61

In methods 1 and 2 the graduations in the measuring apparatus were in one-tenth of a cubic centimeter, while in method 3 they were in one two-hundredths of a cubic centimeter. This accounts for the slight difference shown in method 3. Of the three methods, No. 3 is the most rapid, since the reading can be determined within 15 minutes after the sulphuric acid has finished reacting, making the total test consume only 2 hours, as against from 7 to 17 in the other methods.

METHOD USED IN MAKING UP THE NORMAL ACIDS AND TESTING THEIR STRENGTH.

The ordinary concentrated sulphuric acid contains 95 per cent of acid, or between 35 and 36 times normal. Any acid stronger than this must be made by adding fuming sulphuric acid to the ordinary acid. Strong sulphuric acid and the fuming acid absorb moisture very rapidly from the air, and thus become diluted in a short time. In order to overcome this difficulty the following apparatus was used to weigh the acid for analysis: A small pipette similar to a medicine dropper was inserted in one hole of a two-holed rubber stopper and the other end of the hole plugged with a glass rod. In the other hole was inserted a glass rod bent at the upper end so that the whole arrangement could be hung on the arm of a balance. The weight of the apparatus was then found. In using the apparatus the pipette was removed from the stopper, filled with acid, quickly dried, put back into the stopper, and weighed. The whole apparatus was then carefully washed with water, the washings and acid diluted, titrated with standard alkali, and the result calculated for the strength of the acid in per cent of SO_3. The strengths of the ordinary concentrated acid and the fuming acid were determined in this way, and the percentage of each necessary to form the required mixture calculated. The calculation is a rather simple one, but for the sake of clearness an example is given below:

Percentage of SO_3 required in 37 times normal acid 80.07
Percentage of SO_3 found in the ordinary acid 77.38
Percentage of SO_3 found in the fuming acid 84.56

A unit of ordinary concentrated acid, therefore, contains too little SO_3 by (80.07—77.38) 2.69 per cent, and a unit of the fuming acid too much SO_3 by (84.56—80.07) 4.49 per cent. Consequently it is necessary to mix the two in the proportion of 269 parts of fuming acid (84.56 per cent SO_3) to 449 parts of ordinary concentrated acid (77.38 per cent SO_3) to obtain the 37 times normal acid having 80.07 per cent SO_3. It is always better to run a check analysis on the acid after mixing to make certain that the calculations were correct.

DESCRIPTION OF THE REVISED METHOD.

The revised or modified method finally adopted is as follows:

Ten cubic centimeters of the fraction of creosote to be tested are measured into a Babcock milk bottle. To this is added 40 cubic centimeters of 37 times normal acid, 10 cubic centimeters at a time. The bottle with its contents is shaken for two minutes after each addition of 10 cubic centimeters of acid. After all the acid has been added the bottle is kept at a constant temperature of from 98° to 100° C. for one hour, during which time it is shaken vigorously every 10 minutes. At the end of an hour the bottle is removed, cooled, and filled to the top of the graduation with ordinary sulphuric acid, and then whirled for five minutes in a Babcock separator. The unsulphonated residue is then read off from the graduations. The reading multiplied by 2 gives per cent by volume directly. (Each graduation equals one two-hundredths of a cubic centimeter.)

In well-equipped chemical laboratories the usual steam-jacket ovens, capable of maintaining a temperature of from 98° to 100° C., will keep the reaction mixture of the sulphuric acid and creosote at the proper temperature. It frequently happens, however, that creosotes are analyzed in a laboratory equipped only for that purpose, and for such cases a special steam bath or oven can be made by any tinsmith at small cost. It is essential that the chamber be of sufficient size to completely contain (under the cover) the Babcock bottle; otherwise the exact dimensions of the steam bath are unimportant, and any two vessels of suitable dimensions, which are at hand or can most readily be obtained, may be utilized in its construction. The accompanying figure illustrates the construction of a steam bath for this purpose.

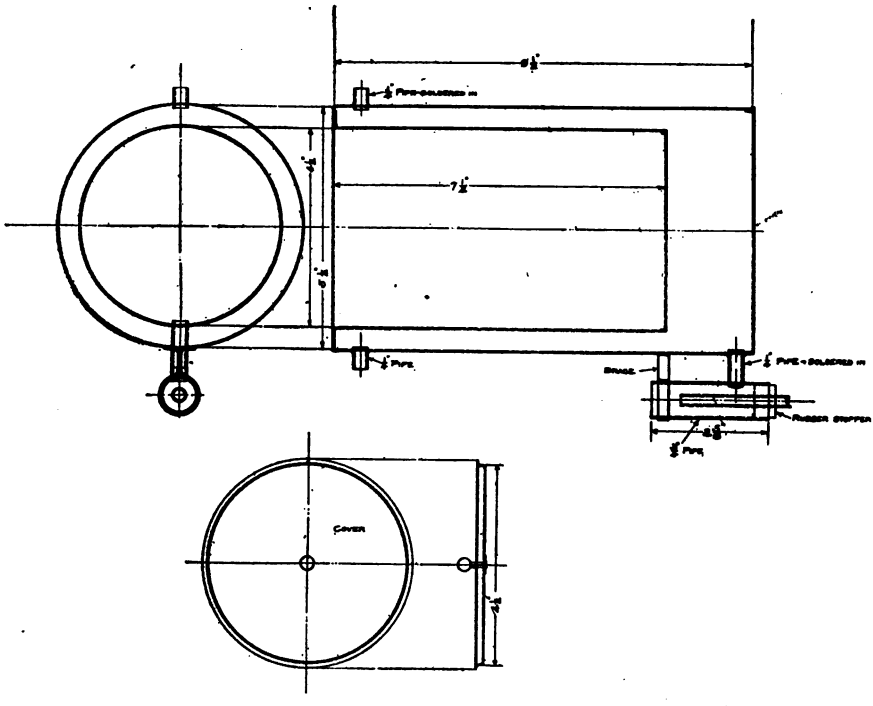

FIG. 1.—Steam bath for sulphonation test in creosote analysis.

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HENRY S. GRAVES, Forester.

THE PREVENTION OF SAP STAIN IN LUMBER.

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THE PREVENTION OF SAP STAIN IN LUMBER.

PURPOSE AND CHARACTER OF THE STUDY.

The chief purpose of this circular is to give results of experimental tests with various chemicals to prevent sap stain in lumber. In addition, a closely related subject, the comparative strength of untreated and chemically treated woods, and of those stained and unstained, is briefly discussed in the light of recent tests. The tests covering the chemical treatments were conducted by the Forest Service in cooperation with the Great Southern Lumber Co., at Bogalusa, La., in 1907 and 1908. Those to determine the strength of sap stained, unstained, and soda-dipped boards were made by the Section of Timber Tests of the Forest Products Laboratory, Madison, Wis., in cooperation with the Globe Lumber Co., of Yellow Pine, La., and the Gilchrist-Fordney Co., of Laurel, Miss. Though the tests were made with southern yellow pine (longleaf pine), certain tests are referred to which were made with western yellow pine in the laboratory of Washington University, St. Louis, Mo.

SAP STAIN AND ITS CAUSES.

When freshly cut sap lumber is piled in the open air to season it frequently becomes discolored in a few days. The stain is different in both cause and appearance from the change of color due to weathering and accumulations of dirt and soot on the boards. It occurs in the sap part of the wood only, and for that reason is called sap stain. It is considered a defect, and lumber attacked by it is reduced in value, partly on account of its unpleasing appearance, but chiefly because many believe that such lumber is not as sound as it was before the stain developed. The discoloration can not be washed off or otherwise removed, for it is not a surface deposit. It lies deep in the underlying cellular structure of the wood, and when once there it remains. The reduction in value of stained lumber results in enormous loss. Sometimes it amounts to $2 per 1,000 feet, sometimes to only 50 cents, or less. Perhaps one-fourth of the annual mill cut of the United States is attacked, but with different degrees of intensity in different regions and at different seasons of the year. The South

suffers most, because climatic conditions—dampness and heat—facilitate the development and spread of the organisms which cause the stain. Estimates for the whole country place the loss from sap stain at about eight and a quarter million dollars. This loss occurs chiefly in low-grade lumber, because such lumber in longleaf pine, one of the chief species attacked, is more largely sapwood than are the higher grades, and therefore more susceptible to infection, and because lower grades of lumber are not often kiln dried, but are stacked in the yard to air season, there to be exposed to attack during the first two or three months of the drying process.

There is not complete accord among all investigators regarding sap stain, but it is very generally agreed among them that it is due to fungi in most cases if not in all.[1]

There are different kinds of stain, at least all are not alike in appearance. That commonly called blue stain is most prevalent and causes greatest loss. Fungus spores, which are very small and powderlike bodies corresponding to the seeds of flowering plants, are carried by the air and find lodgment on all exposed surfaces. Freshly sawed lumber presents ideal conditions for their development. They cling tenaciously and quickly sprout fine threads, called mycelia, which they send into the wood in search of food. This they find in the wood cells, hollow tubes too small to be seen except with a microscope, but which in the aggregate make up much of the wood structure. When greatly magnified they bear considerable resemblance to honeycomb, and, like honeycomb, they are more or less filled with food substances. The discoloration of the wood by which the presence of the fungus is detected is believed to be due to an optical effect produced by the brown fungus threads when seen through the yellowish cell walls.

To prevent the sap staining of lumber it is necessary either to attack the fungus before it has time to infect the wood or else to render the wood proof against infection. As a means of doing these things the surface of the wood might be so poisoned that spores of fungus lodging there would be killed, or the contents of the wood cells might be made unfit for the nourishment of the mycelia which penetrated them.

MATERIALS AND METHODS USED.

Experiments and tests were made with a number of chemicals to determine whether they might be applied to lumber in a way to render it immune from attacks of fungus between cutting time at the mill and the time when the wood had sufficiently air seasoned in the yard to place it out of danger. This period usually covers from 30 to 60 days. If lumber can be successfully carried through the critical

[1] Some investigators would attribute it to enzymes, or the unorganized ferments, instead of to fungi. Enzymes, however, have not been studied much in detail, and comparatively little is known of them.

period, the air seasoning will have advanced far enough to prevent any fungus spores that may lodge upon the surface from doing damage. At the time the experiments were made little information was available to show the efficiency of various chemicals in preventing attacks from sap-staining fungi.

CHEMICALS.

The chemicals selected for the tests were grouped in three classes, each class designed to act in a different way:

Class 1 contained deliquescent salts, such as calcium chloride and magnesium chloride, the purpose being to keep the boards in a thoroughly saturated condition.

Class 2 included borax, sodium carbonate, sodium bicarbonate, lime, and sodium hydroxide. These were selected to neutralize any acid substances that might be present in or formed by the wood.

Class 3 contained chemicals that were expected to poison the fungi, and included zinc and mercuric chlorides, copper sulphate, phenol, and naphthalene flakes. All of these, except the last, were mixed in

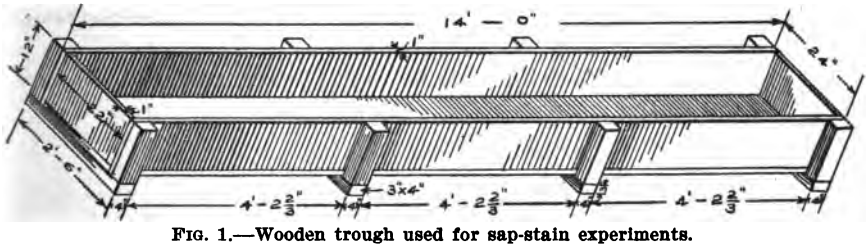

FIG. 1.—Wooden trough used for sap-stain experiments.

a wooden trough at atmospheric temperature. No artificial heat was used except with the borax solution, when the water was warmed to about 115° F. The naphthalene flakes were simply sprinkled between the freshly cut boards.

WOOD.

Sap longleaf pine boards were used in the tests. They were selected from sound, green logs, free from stain. Some were planed immediately after they were sawed and before the treatment. They were 1 inch thick, 12 inches wide, and 12 feet long, and about 1,000 feet were used in each test. The boards were treated fresh from the saw and were then piled in the yard to season.

APPARATUS.

A wooden trough, 2 feet wide, 1 foot deep, and 14 feet long, contained the chemicals. (Fig. 1.) The immersion of the boards in the fluid was done by hand. They were held in less than a minute and

then stacked in the yard, half in solid piles, to put the preservative to a most severe test, and half in open piles, according to ordinary mill methods, allowing 2-inch air chambers and using cross sticks 1 inch thick. To make the test as severe as possible, the piles were placed in a portion of the seasoning yard where the air was constantly stirred and filled with dust from passing engines and teams.

In large operations, instead of immersing the boards by hand, an endless chain may be used, by means of which they can be dipped in the tank containing the solution. Another method of mechanically applying the chemical consists in applying the preservative as they pass along a roller conveyor. (Fig. 2.) The essential parts of this apparatus consist of a closed loop or sprayer of pipes, perforated with ⅛-inch holes spaced one-fourth inch apart. To prevent waste of the solution, the sprayer is covered with a sheet-iron hood, by which the excess liquid is conducted by gravity back to the storage tank. Constant circulation of the solution through the sprayer is maintained by the use of a centrifugal pump connected with the driving motor. The boards are sprayed on all surfaces as they pass along the rollers, and brushes remove the excess solution. Some mills plane their boards green, and in such cases the spraying apparatus could easily be coupled to the planing machinery.

As a basis for comparison the untreated boards were piled in the same manner as the treated.

EXAMINING THE BOARDS.

While the tests were in progress the piles of boards were torn down about every two weeks, examined for stain, weighed, and restacked. Attacks by insects were also noted. The following scheme was adopted for classifying the boards:

Clear.—Boards with no stain and perfectly bright.

Light.—Boards with from 1 to 10 per cent of their surface stained.

Medium.—Boards with from 11 to 25 per cent of their surface stained.

Heavy.—Boards with more than 25 per cent of their surface stained.

Tests with various chemicals were continued during two or three months, and the results are shown in Table I, and for some of the more important preservatives graphically in figure 3.

RESULTS OF EXPERIMENTS.

UNTREATED BOARDS.

All untreated boards placed in solid piles were stained in less than one month. Those piled openly were not so severely attacked, but only 35 per cent of them remained bright at the end of one month's exposure. This shows clearly the advantage of piling boards in a way to permit the free circulation of air.

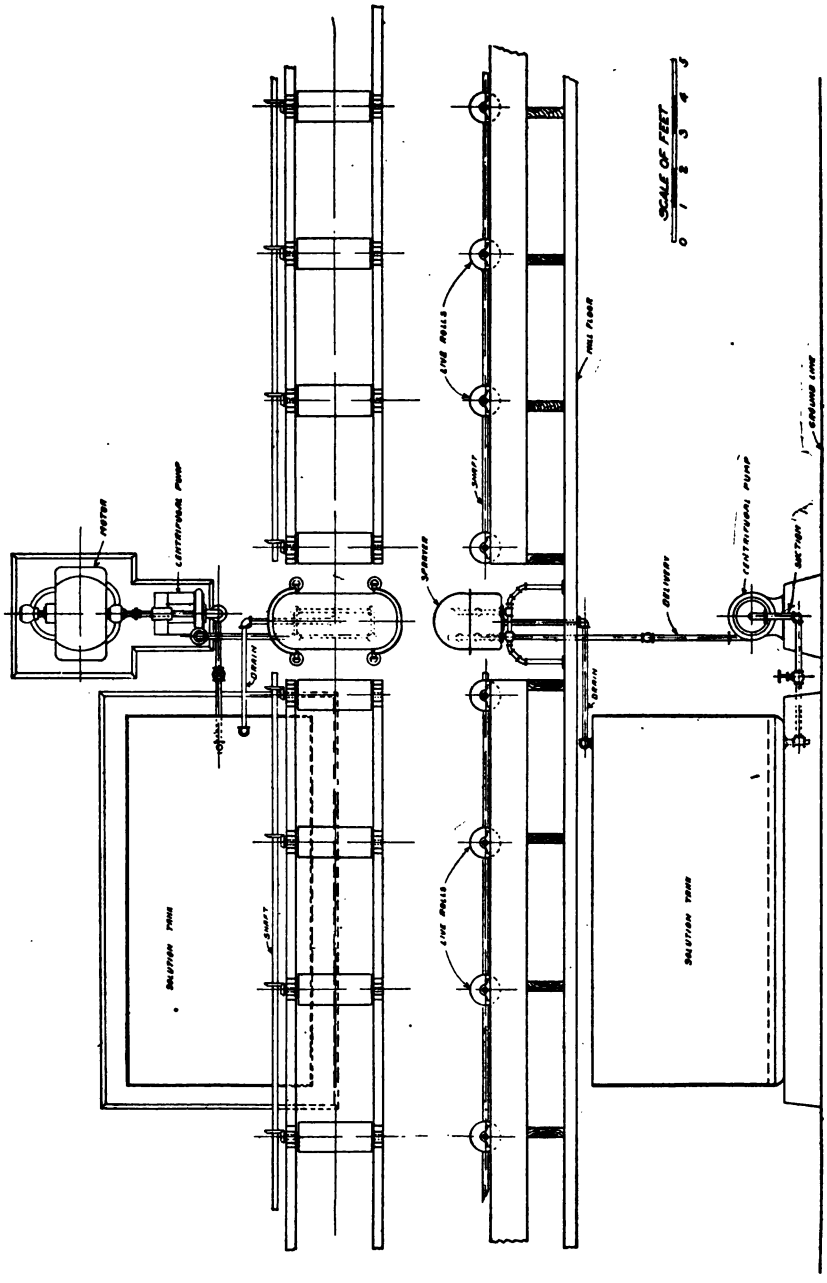

FIG. 2.—General arrangement of spraying machine for applying sap-stain solutions.

CALCIUM AND MAGNESIUM CHLORIDES.

Five per cent solutions of these chemicals were used, the sole purpose being to keep the boards moist. The dipped boards were piled solidly and examined at the end of two weeks. Practically all were heavily stained. This seemed to show so conclusively that stain can

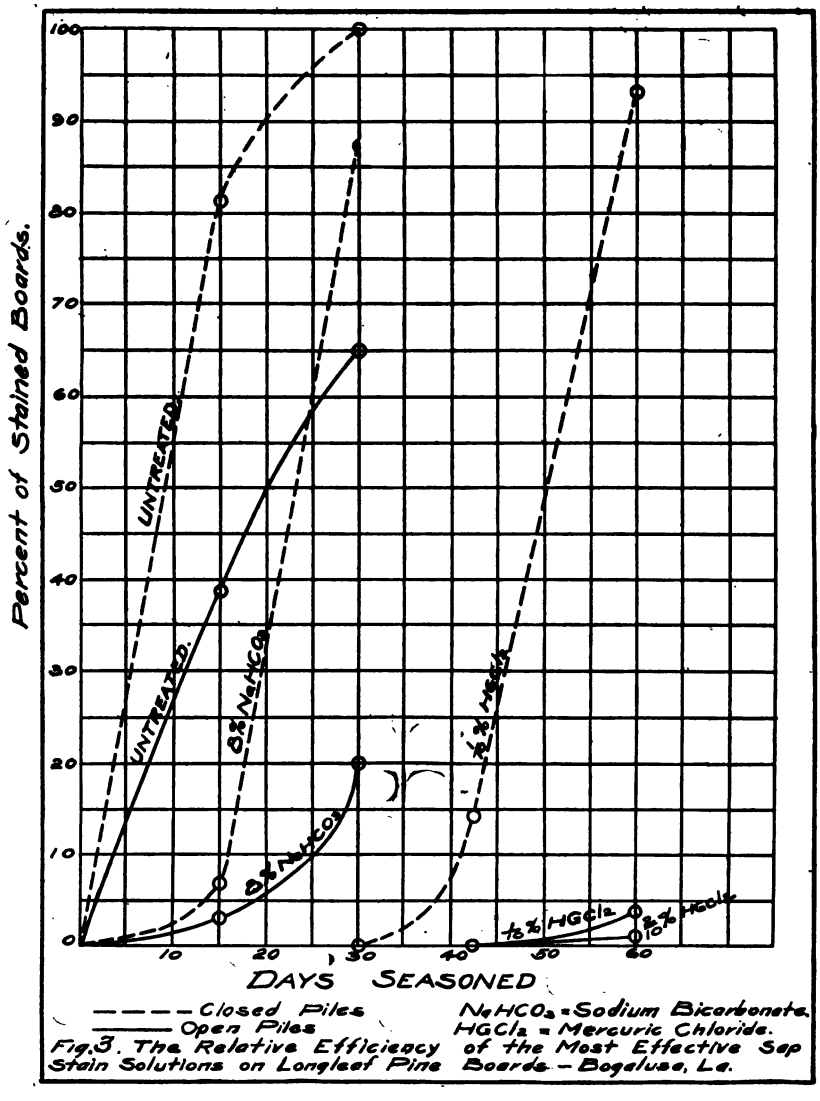

Fig. 3. The Relative Efficiency of the Most Effective Sap Stain Solutions on Longleaf Pine Boards — Bogalusa, La.

not be prevented by keeping the boards moist that further experiments along that line were discontinued.

BORAX.

A 5 per cent solution of borax was used. The boards treated with it, in both open and close piles, were attacked by stain. All boards

in the close piles and 75 per cent of those in the open piles were stained at the end of two weeks. After one month's exposure 92 per cent of the boards in the open piles were stained. It is apparent, therefore, that this solution was not effective in preventing attack from sap-staining fungi. Moreover, boards treated with it are frequently covered with a streaky white precipitate.

SODIUM CARBONATE AND LIME.

A solution was made of 4 per cent sodium carbonate and 2 per cent unslaked lime. At the end of two weeks 76 per cent of the closely piled boards were discolored, while all in the open piles remained clear. At the end of another two weeks most of the boards in the open piles showed stain, and the experiment was discontinued. This solution left streaky white precipitates on the surface of the wood.

SODIUM HYDROXIDE.

Boards dipped in a 3 per cent solution of this chemical and placed in close piles were practically all stained at the end of 30 days. A 5 per cent solution was then used, and the boards placed in both open and close piles. After one month's exposure 98 per cent of the boards in close piles and about 70 per cent in the open piles had been attacked. These results were very unsatisfactory and the experiment was discontinued. The boards were stained a vivid yellow, though this color became less pronounced on long exposure.

SODIUM BICARBONATE.

Solutions of this chemical from 5 to 15 per cent in concentration were used. At the end of one month 17 per cent of the boards treated with the 5 per cent solution and exposed in an open pile and 97 per cent in a close pile were stained. With an 8 per cent solution and an exposure of 30 days only 20 per cent of the boards in the open pile were discolored, but in the close pile 87 per cent were affected. When a 12 per cent solution was employed all boards in the open pile remained bright at the end of a month, but 70 per cent of those in the close pile were stained. Boards treated with a 15 per cent solution and placed in open piles were free from stain at the end of 30 days. Practically all of those in the solid pile were attacked. These results show that the solutions of sodium bicarbonate were better than any of the other alkalis used. The heavier concentrations were effective when the boards were placed in open piles, but were not effective when they were close piled. The treated wood was stained yellow, but the color partly disappeared with time. Sodium bicarbonate has a tendency to leave a streaky precipitate on the surface of the boards. If the lumber is planed before shipment the objection on account of the precipitates is removed, but a number of manufacturers contend that in planing the lumber their machine knives are quickly dulled.

However, tests made at the Forest Products Laboratory showed no marked tendency on the part of soda-dipped boards to increase the dulling of knives. Of several representative mills which planed soda-dipped lumber, about one-half were of the opinion that the treated boards dulled knives more rapidly than the untreated and one-half were of the contrary opinion. It appears that careless dipping and impure chemicals increase the rapidity of the knives dulling.

PHENOL (CARBOLIC ACID).

A test was made with a 2 per cent solution of this chemical, the boards being placed both in open and close piles. At the end of 30 days 90 per cent of those in open and 98 per cent of those in close piles were stained. The test was therefore carried no further.

NAPHTHALENE FLAKES.

The flakes were sprinkled between the boards, which were placed in a close pile. At the end of 30 days 68 per cent were discolored, and the experiment was discontinued. The test also showed that it is impracticable to apply a preservative in this manner because of the great labor involved.

COPPER SULPHATE.

Solutions of copper sulphate varying from 0.5 to 5 per cent were used. The 0.5 per cent solution proved wholly ineffective. After one month's exposure 77 per cent of the boards in the open pile and all of those in the close pile were stained. The results secured with the 1.5 per cent solution were very little better. All of the boards treated with the 5 per cent solution were close piled. At the end of one month 75 per cent were stained. These solutions discolor the lumber with vivid green streaks, which would unquestionably lessen its sale value.

ZINC CHLORIDE.

Tests were made with 1 and 5 per cent solutions of zinc chloride. Ninety per cent of the boards dipped in the 1 per cent solution and placed in open piles were discolored at the end of 30 days. All of those in the close piles were stained. When the 5 per cent solution was used, 55 per cent of the open-piled boards and all of those in the close pile were attacked during a month's exposure.

MERCURIC CHLORIDE.

Solutions of mercuric chloride ranging in strength from 0.075 to 1 per cent were used. Eighty-six per cent of the boards treated with the 0.075 per cent solution and exposed in solid piles were stained at the end of 30 days, but only 4 per cent of those in the open piles showed discoloration. The 0.1 per cent solution was more effective.

All boards treated with it and placed in open piles were clear at the end of 42 days, while only 14 per cent of those in close piles had been attacked. Two months after treatment only 4 per cent in the open pile were stained, but 93 per cent in the close pile showed discoloration. With a 0.2 per cent solution only 1 per cent of the open-piled boards was stained at the end of two months. In the close pile, however, 85 per cent were attacked. With the 1 per cent solution all boards in the open pile were free from stain after two months' exposure and only 4 per cent of those in the solid pile had been attacked. As far as effectiveness in preventing stain is concerned mercuric chloride solutions gave the best results. Moreover, there is no precipitation on or discoloration of the boards. However, on account of their poisonous nature, and their activity in corroding metal brought into contact with them, such solutions are not recommended for general work.

TABLE I.—*Efficiency of various chemicals in preventing sap stain.*

Pile No.	Treatment.	Method of piling.	Per cent of stain during seasoning period.							
			Clear.				Light.			
			Two weeks.	One month.	Six weeks.	Two months.	Two weeks.	One month.	Six weeks.	Two months.
*1	Untreated	Open	61	35	.....	.....	17	38	.....	.....
*2	do	Closed	19	0	.....	.....	4	0	.....	.....
3	5% magnesium chloride	do	0	.....	.....	.....	1	.....	.....	.....
4	5% calcium chloride	do	8	.....	.....	.....	4	.....	.....	.....
5	5% borax	Open	25	8	.....	.....	43	59	.....	.....
6	do	Closed	0	0	.....	.....	22	0	.....	.....
7	4% sodium carbonate, 2% lime	Open	100	.....	.....	.....	0	.....	.....	.....
8	do	Closed	24	.....	.....	.....	39	.....	.....	.....
*9	3% sodium hydroxide	do	75	5	.....	.....	25	60	.....	.....
10	5% sodium hydroxide	do	91	2	.....	.....	9	20	.....	.....
11	do	Open	100	30	.....	.....	0	63	.....	.....
*12	5% sodium bicarbonate	do	94	83	.....	.....	6	15	.....	.....
*13	do	Closed	57	3	.....	.....	14	3	.....	.....
*14	8% sodium bicarbonate	Open	97	80	.....	.....	3	17	.....	.....
*15	do	Closed	93	13	.....	.....	6	21	.....	.....
*16	12% sodium bicarbonate	Open	100	100	.....	.....	0	0	.....	.....
*17	do	Closed	96	30	.....	.....	4	16	.....	.....
*18	15% sodium bicarbonate	Open	100	100	.....	.....	0	0	.....	.....
*19	do	Closed	100	9	.....	.....	0	10	.....	.....
20	2% phenol	Open	84	10	.....	.....	16	82	.....	.....
21	do	Closed	5	2	.....	.....	22	2	.....	.....
22	Naphthalene	do	80	32	.....	.....	12	27	.....	.....
*23	0.5% copper sulphate	Open	30	23	.....	.....	18	21	.....	.....
*24	do	Closed	3	0	.....	.....	1	0	.....	.....
*25	1.5% copper sulphate	Open	58	40	.....	.....	17	25	.....	.....
*26	do	Closed	14	4	.....	.....	1	0	.....	.....
*21	5% copper sulphate	do	87	25	.....	.....	13	38	.....	.....
*22	1% zinc chloride	Open	26	10	.....	.....	15	15	.....	.....
*23	do	Closed	0	0	.....	.....	1	0	.....	.....
*24	5% zinc chloride	Open	78	45	.....	.....	13	25	.....	.....
*25	do	Closed	25	0	.....	.....	22	3	.....	.....
26	0.075% mercuric chloride	Open	100	96	.....	.....	0	4	.....	.....
27	do	Closed	77	14	.....	.....	14	45	.....	.....
28	0.1% mercuric chloride	Open	100	100	100	96	0	0	0	4
29	do	Closed	100	100	86	7	0	0	12	9
30	0.2% mercuric chloride	Open	100	100	100	99	0	0	0	1
31	do	Closed	100	100	97	15	0	0	3	33
32	1% mercuric chloride	Open	100	100	100	100	0	0	0	0
33	do	Closed	100	100	96	96	0	0	0	0

TABLE I.—*Efficiency of various chemicals in preventing sap stain*—Continued.

Pile No.	Treatment.	Method of piling.	Per cent of stain during seasoning period.							
			Medium.				Heavy.			
			Two weeks.	One month.	Six weeks.	Two months.	Two weeks.	One month.	Six weeks.	Two months.
*1	Untreated	Open	10	14	.....	.....	12	13	.....	.....
*2	do	Closed	11	3	.....	.....	66	97	.....	.....
3	5% magnesium chloride	do	3	.....	.....	.....	96	.....	.....	.....
4	5% calcium chloride	do	8	.....	.....	.....	80	.....	.....	.....
5	5% borax	Open	22	23	.....	.....	10	10	.....	.....
6	do	Closed	16	0	.....	.....	62	100	.....	.....
7	4% sodium carbonate, 2% lime	Open	0	.....	.....	.....	0	.....	.....	.....
8	do	Closed	29	.....	.....	.....	8	.....	.....	.....
*9	3% sodium hydroxide	do	0	27	.....	.....	0	8	.....	.....
10	5% sodium hydroxide	do	0	58	.....	.....	0	20	.....	.....
11	do	Open	0	7	.....	.....	0	0	.....	.....
*12	5% sodium bicarbonate	do	0	1	.....	.....	0	1	.....	.....
*13	do	Closed	13	10	.....	.....	16	84	.....	.....
*14	8% sodium bicarbonate	Open	0	3	.....	.....	0	0	.....	.....
*15	do	Closed	1	26	.....	.....	0	40	.....	.....
*16	12% sodium bicarbonate	Open	0	0	.....	.....	0	0	.....	.....
*17	do	Closed	0	21	.....	.....	0	33	.....	.....
*18	15% sodium bicarbonate	Open	0	0	.....	.....	0	0	.....	.....
*19	do	Closed	0	18	.....	.....	0	63	.....	.....
20	2% phenol	Open	0	3	.....	.....	0	5	.....	.....
21	do	Closed	22	0	.....	.....	51	96	.....	.....
22	Naphthalene	do	8	5	.....	.....	0	38	.....	.....
*23	0.5% copper sulphate	Open	25	21	.....	.....	27	35	.....	.....
*24	do	Closed	5	0	.....	.....	91	100	.....	.....
*25	1.5% copper sulphate	Open	13	18	.....	.....	12	17	.....	.....
*26	do	Closed	8	16	.....	.....	77	80	.....	.....
*21	5% copper sulphate	do	0	17	.....	.....	0	20	.....	.....
*22	1% zinc chloride	Open	9	22	.....	.....	50	53	.....	.....
*23	do	Closed	0	1	.....	.....	99	99	.....	.....
*24	5% zinc chloride	Open	9	18	.....	.....	0	12	.....	.....
*25	do	Closed	17	25	.....	.....	36	72	.....	.....
26	0.075% mercuric chloride	Open	0	0	.....	.....	0	0	.....	.....
27	do	Closed	6	30	.....	.....	3	11	.....	.....
28	0.1% mercuric chloride	Open	0	0	0	0	0	0	0	0
29	do	Closed	0	0	2	14	0	0	0	70
30	0.2% mercuric chloride	Open	0	0	0	0	0	0	0	0
31	do	Closed	0	0	0	24	0	0	0	28
32	1% mercuric chloride	Open	0	0	0	0	0	0	0	0
33	do	Closed	0	0	2	2	0	0	2	2

NOTE.—Piles marked with an asterisk (*) were treated in the fall of 1907; those not marked were treated in the fall of 1908.

RATE OF SEASONING.

When the test piles of lumber were taken apart the boards were weighed to determine the rate at which seasoning had taken place. It was found that boards in the open piles dried twice as fast as those in solid piles. Rapid decrease in weight is a distinct advantage from the shipper's standpoint, on account of decreased freight charges. It has the additional advantage that the boards can be more effectively protected against stain and insect attacks. The chief objection to open piling is that it takes more yard space, but considering its advantages it is vastly superior to any known method of solid stacking. The results secured in the seasoning test are shown graphically in figure 4.

INSECT ATTACKS.

Some depreciation in the value of the lumber used in the experimental work was caused by the attacks of wood-boring insects. During the progress of the experiments observations were made to determine what effect the different methods of stacking and the various

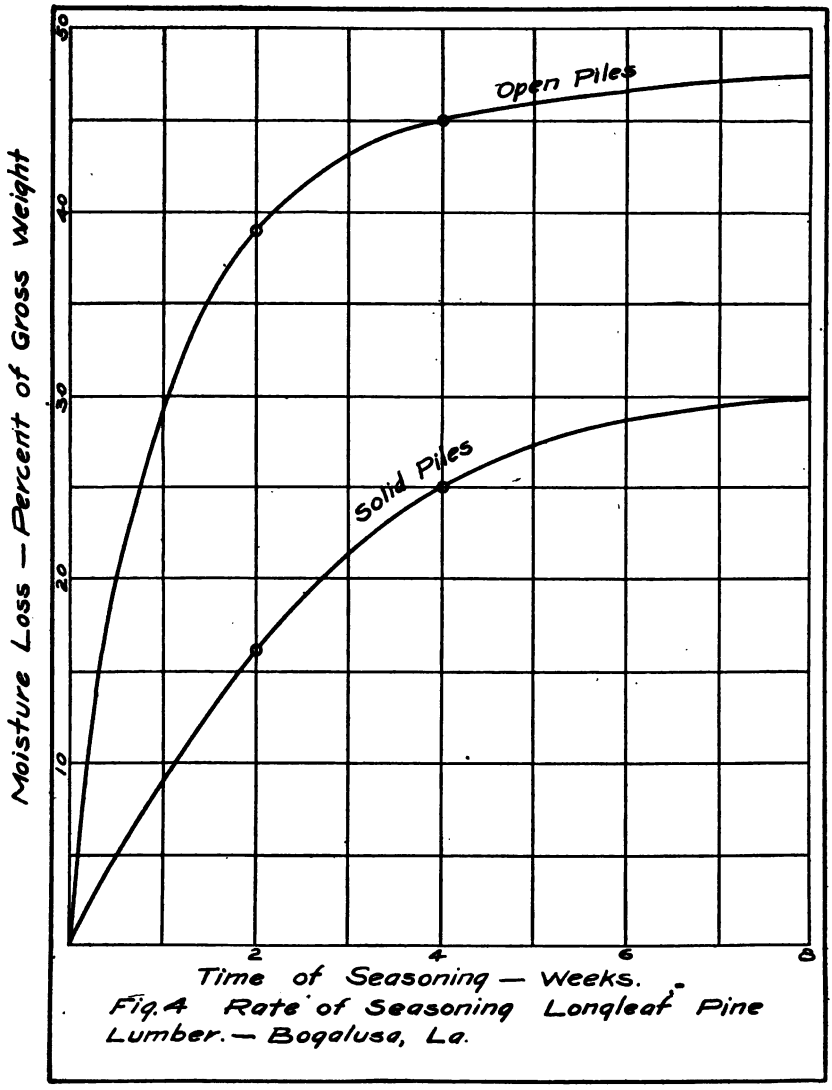

Fig. 4 Rate of Seasoning Longleaf Pine Lumber. — Bogalusa, La.

chemicals used had on the activities of the insects. It was found that in the open piles practically no insect damage occurred, but that in close piles the sapwood was frequently bored into, especially where bark adhered to it. Such attacks were most noticeable in wood treated with deliquescent salts, which has a tendency to keep the surface moist. It appears, therefore, that rapid drying lessens insect

damage. No insect attacks were noticed where boards had been treated with mercuric chloride solutions.

HARDNESS AND STRENGTH.

TREATED AND UNTREATED MATERIAL.

Incidental to the application of chemicals to prevent sap stain is the question whether such chemicals affect the strength of the wood. In this discussion bicarbonate solutions alone are considered. It has been claimed that boards dipped in that chemical become brash and brittle, and this has at times resulted in a discrimination against soda-dipped lumber. The Forest Products Laboratory, therefore, conducted tests to ascertain what effect, if any, such treatment has upon the strength of wood.

A number of shortleaf and longleaf pine boards, 1½ by 4 inches by 16 feet, treated and untreated, were shipped to the laboratory by the Globe Lumber Co., of Yellow Pine, La., and the Gilchrist-Fordney Co., of Laurel, Miss. The boards were carefully matched, cut into test specimens, and subjected to static bending over a 26-inch span, center loaded. Tests were made in accordance with standard methods described in Forest Service Circular 38. Additional tests to ascertain hardness were made by pressing a steel ball, seven-sixteenths of an inch in diameter, into the wood and reading the maximum load required up to the time the ball reached a penetration equal to one-half its diameter. The results secured by this test are given in Table II. They show that the soda-dipped wood is slightly stronger, stiffer, and tougher than untreated wood, but the difference is so small that it may be due to inherent differences in the wood. It is safe to conclude, however, that these properties are not reduced by treatment with the sodium bicarbonate. The soda-dipped shortleaf pine showed a slight increase in surface hardness, which, however, disappeared after the wood became thoroughly air dry. Tests on the longleaf pine showed that the treatment made the surface no harder. If any increased hardness appeared at first it disappeared within three months.

TABLE II.—*Summary of tests showing the strength of soda-dipped boards.*

Species.	Moisture per cent at time of test.	Condition.	Strength in static bending.				Hardness, total load (pounds).
			F. S. at E. L. (pounds per square inch).	M. of R. (pounds per square inch).	M. of E. (1,000 pounds per square inch).	Res. to M. L. (pounds per cubic inch).	
Shortleaf pine	17.7	Untreated	6,295	10,040	1,559	9.6	857
	17.7	Soda dipped	7,070	10,964	1,638	10.9	885
	9.5	Untreated	7,729	13,736	1,792	9.8	954
	9.5	Soda dipped	8,310	14,414	1,882	10.1	952
Longleaf pine	17.6	Untreated	7,322	11,679	1,785	8.5	772
	17.3	Soda dipped	8,292	12,594	1,904	8.93	762
	7.32	Untreated	10,932	16,759	2,187	11.97	910
	7.72	Soda dipped	10,897	18,306	2,250	13.12	952

STAINED AND UNSTAINED MATERIAL.

The tests to determine the effect of sap stain on the hardness and strength of wood were made at Washington University, St. Louis, Mo., with stained and unstained yellow pine. The conclusion reached was that the blue wood is slightly stronger, both when compressed endwise and when broken crosswise. This result is probably due to the fact that at the time the tests were made the stained wood was slightly drier than the natural wood with which it was compared, for it is improbable that the presence of fungus threads in wood in any way strengthens the fiber. However that may be, these tests show beyond doubt that for all practical purposes the blued wood is as strong as the green wood.

In order to secure additional data on the subject a number of experiments were carried on at the Forest Products Laboratory, at Madison, using stained and unstained longleaf and shortleaf pine. The boards were first carefully matched and then tested in static bending over a 26-inch span, with the sides nearest the pith kept uppermost. In addition, hardness tests were made in the same manner as described on page 16, where the steel ball was used. In all, 750 tests were made to determine the strength of stained and unstained pine, and the results are given in Table III. They show that for the same moisture content the heavily stained shortleaf pine was slightly weaker, less tough, and showed less surface hardness than the unstained. In the longleaf pine, which was only slightly stained, the differences in strength, toughness, and hardness between stained and unstained boards were too slight to be noticed. These tests tend to substantiate the results reached in the St. Louis experiments.

TABLE III.—*Summary of tests showing the strength of sap-stained wood.*

Species.	Moisture per cent at time of test.	Condition.	Strength in static bending.				Hardness, total load (pounds).
			F. S. at E. L. (pounds per square inch).	M. of R. (pounds per square inch).	M. of E. (1,000 pounds per square inch).	Res. to M. L. (pounds per cubic inch).	
Shortleaf pine	17.7	Unstained	6,295	10,040	1,559	9.6	857
	9.5	do	7,729	13,736	1,792	9.8	954
	8.7	Stained	8,902	14,061	1,883	9.4	852
Longleaf pine	17.6	Unstained	7,322	11,679	1,785	8.5	772
	7.32	do	10,982	16,759	2,187	11.97	910
	7.34	Stained	11,296	17,858	2,374	11.77	883

INFLAMMABILITY OF SODA-DIPPED WOOD.

It has been claimed that shavings from soda-dipped wood can not readily be burned, and tests were made at the Madison laboratory to procure reliable data on the subject. Shavings treated with bicar-

bonate of soda were used. An air-seasoned plank of loblolly pine was run through a planing machine and the shavings divided into four groups, one of which was kept in an untreated condition. The three others were dipped in solutions of sodium bicarbonate of 2, 4, and 8 per cent, respectively, for 16 hours at room temperature. The shavings were then dried and 200 grams of each group were placed on an iron screen and subjected to the flame of a Bunsen burner for 60 seconds. The time required for the shavings to ignite and the duration of the flame are shown below.

Treatment.	Time to ignite.	Duration of flame.
Natural	53 seconds	2 minutes 15 seconds.
2 per cent sodium bicarbonate	55 seconds	3 minutes.
4 per cent sodium bicarbonate	2 minutes 13 seconds	4 minutes 37 seconds.
8 per cent sodium bicarbonate	2 minutes 25 seconds	5 minutes 45 seconds.

The conditions of this test were more severe than those likely to occur in practice, because the shavings were soaked a long time in the solution, while in practice the boards are simply dipped in it. The test shows that sodium bicarbonate has a tendency to lessen the liability of wood to ignite, but the decrease is so slight that it is believed to have no practical significance.

COST OF TREATMENT.

If the chemical solutions are applied by hand, all the apparatus necessary is a water-tight trough, shown in figure 1, which costs about $15. The cost of applying an effective bicarbonate solution by that method is from 20 to 25 cents per thousand board feet. If the boards are dipped by means of an endless chain in a tank containing the solution, the cost of the apparatus will be about $500. If the solution is applied by a sprayer, such as is shown in figure 2, the apparatus will cost from $500 to $600. Table IV shows the estimated cost of applying sap-stain solutions by hand and by machine.

TABLE IV.—*Estimated cost, per 1,000 board feet, of treating boards with sap-stain solutions.*

Solution.	Chemical.	Labor by—		Total by—	
		Hand.	Machine.	Hand.	Machine.
0.1% $HgCl_2$[a]	$0.04	$0.15	$0.01	$0.19	$0.05
0.2% $HgCl_2$[a]	.08	.15	.01	.23	.09
0.1% $HgCl_2$[a]+0.1% HCl[b]	.05	.15	.01	.20	.06
0.2% $HgCl_2$+0.1% HCl	.09	.15	.01	.24	.10
8% $NaHCO_3$[c]	.06	.15	.01	.21	.07
12% $NaHCO_3$	.09	.15	.01	.24	.10

[a] $HgCl_2$=mercuric chloride. [b] HCl=hydrochloric acid. [c] $NaHCO_3$=sodium bicarbonate.

CONCLUSIONS.

The following conclusions may be drawn from the tests:

1. Freshly cut sap lumber when stacked in the yard to dry should be stacked in open piles to permit the free circulation of air. Boards so piled season in about half the time required for those piled in close piles. Open piles, moreover, are not so severely attacked by insects and are more effectively protected against sap stain.

2. In commercial work sap stain can be most effectively prevented by dipping boards in solutions of sodium bicarbonate. Such solutions, though they give fairly good results, leave much to be desired. The strength of the solution should be determined by the severity of the conditions under which the boards are to season, but in general it will require from 5 to 10 per cent. Care should be taken that the chemical used is not mixed with adulterants.

3. The best results in preventing sap stain were secured with mercuric chloride solutions, but on account of their poisonous nature they are not recommended for general use.

4. The solution made by mixing sodium carbonate and lime was not as effective as one of sodium bicarbonate alone. Moreover, it had a greater tendency to streak the surface of the boards with a white precipitate.

5. Solutions of magnesium chloride, calcium chloride, sodium hydroxide, phenol, copper sulphate, and zinc chloride did not prevent sap stain; nor did sprinkling the boards with naphthalene flakes give satisfactory results.

6. On account of cheapness and facility in operation, it is recommended that sap-stain solutions be applied to the boards by machinery. If this is done, the cost of treating lumber with solutions of sodium bicarbonate will amount to from 7 to 10 cents per 1,000 board feet.

7. The indications are that shavings planed from soda-dipped boards do not burn as readily as those from untreated boards, but the difference in inflammability is so slight that for commercial purposes it may be neglected.

8. At the same moisture content sap-stained boards are slightly weaker than those free from stain, but the difference is so small as to be of no practical importance.

9. Soda-dipped lumber is a little stronger, stiffer, tougher, and has a greater surface hardness than natural lumber, but these differences are exceedingly small and for practical purposes may be neglected.

Approved.

JAMES WILSON,
Secretary of Agriculture.

WASHINGTON, D. C., *September 20, 1911.*

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HENRY S. GRAVES, Forester.

FOREST PRODUCTS LABORATORY SERIES.

MECHANICAL PROPERTIES OF REDWOOD.

BY

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WASHINGTON:
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MECHANICAL PROPERTIES OF REDWOOD.

THE STUDY.

This circular presents the results of a series of tests made to determine the mechanical properties of redwood.[1] They were made at laboratories of the Forest Service conducted in cooperation with the University of California, at Berkeley, and with the University of Washington, at Seattle.

The stringers and joists used in the tests were furnished without cost by the California Redwood Association. The material was selected at mills in Mendocino and Humboldt Counties, California, by representatives of the Forest Service. Care was taken to include timber which was representative of the range of quality found in market material.

THE REDWOOD OF COMMERCE.

DISTRIBUTION.

Redwood (*Sequoia sempervirens*) grows on the California coast in a strip extending inland from 10 to 30 miles and extending from the northern border of the State southward to a little below Santa Barbara. Redwood may be confused with the bigtree (*Sequoia washingtoniana*), noted for its size and age, but these "big trees" are no longer used for lumber, except in cases where they are blown down.

APPEARANCE AND CHARACTERISTICS OF THE WOOD.

The heartwood varies in color from a light cherry to a dark mahogany. The narrow band of sapwood is almost white. The wood is generally straight-grained and is comparatively light and soft, though individual pieces may be very hard and heavy and have an irregular grain. The number of annual rings in cross section of the material tested varied from 10 to 50 in an inch. The bark is reddish-brown in color and very fibrous.

USES.

Redwood is used for all kinds of construction and finishing purposes, for ties, shingles, paving blocks, telephone and telegraph poles, and tank and pipe staves. In Australia and on the Pacific

[1] Forest Service Bulletin 38, The Redwood, includes a study of the tree, of the brown-rot disease of the redwood, and of its insect enemies.

coast it is extensively used in the manufacture of sash and doors. Redwood ties equipped with tie plates laid in the valley between San Francisco and Los Angeles have given from 10 to 12 years' service. The adoption of a larger tie plate is expected to prolong the period of service, since from 80 to 85 per cent of the removals were due to mechanical wear. These ties were all split from logs a considerable distance below the limbs. Sawed ties and ties cut from limbs are considered less desirable. Immunity from decay and the ravages of white ants makes redwood desirable for tunnel timbers, foundation work, mudsills, curbing, fluming, paving blocks, fence posts, and telephone and telegraph poles. Redwood resists fire well, and even when ignited burns very slowly. It checks but little when exposed to the sun, and is practically free from resin. These properties make it especially suitable for use in buildings.

MATERIAL FOR THE TESTS.

The test material was divided into two classes.

The first class included stringers and joists which contain defects such as knots and checks present in timber purchased on the market. The stringers were of three sizes—8 by 16 inches by 16 feet, 6 by 12 inches by 16 feet, and 7 by 9 inches by 16 feet. The joists were of four sizes—3 by 14 inches by 16 feet, 2 by 12 inches by 16 feet, 2 by 10 inches by 16 feet, and 2 by 8 inches by 16 feet. There were 10 of each size. The purpose of the tests on this material was to secure strength values for use in design; to find out whether there were differences in strength values of timber from different localities, and to determine the influence of seasoning and defects on the strength of commercial-sized timbers.

The second class was made up of small, clear, straight-grained specimens cut from the uninjured portions of the tested stringers and joists, and these in turn were tested to study the effects on their strength of the rate of growth of the proportion of summerwood and of the weight. For such studies only perfect, clear material can be used.

METHODS OF TESTS.[1]

Four kinds of tests were made, to show strength in bending, in compression parallel to grain, in compression perpendicular to grain, and in resistance to shearing.

BENDING TESTS.

In the bending tests, the specimens were supported near the ends and the load applied either at the center or at two points each one-third the length of the span from the end supports. This latter

[1] For a more complete description of the methods of test employed by the Forest Service see Bulletin 108, Tests of Structural Timbers, by McGarvey Cline and A. L. Heim.

method is termed third-point loading. Center loading was used in the tests of small, clear specimens, 2 by 2 by 30 inches; third-point loading, which more nearly corresponds to the conditions to which a beam is subjected in structural work, was used in testing the stringers and joists. In the tests of joists a special support was used at the ends and third-points to keep the joist from tipping over. The tests were made with a universal testing machine and the load was applied gradually and continuously until the pieces failed. The amount of bending or deflection at the center of the piece was noted at regular increments of load. Four factors were calculated from the data derived from each bending test, all in terms of pounds per square inch. These were:

Fiber stress at elastic limit, which represents the greatest stress that a beam can sustain under a load from which it will recover without permanent deflection.

Modulus of rupture, which represents the greatest computed stress in a beam which has been loaded to the breaking point.

Modulus of elasticity, which is a factor computed from the relation between the load and deflection within the elastic limit and which represents the stiffness of the piece of wood under test.

Horizontal shear, which represents the force that tends to split the beam under test into two halves along the neutral plane, for example the plane between the upper and lower halves when the beam is horizontal.

COMPRESSION PARALLEL TO THE GRAIN.

In the tests for compression parallel to the grain two sizes of specimens were used, 6-inch by 6-inch by 24-inch pieces cut from the stringers, and 2 by 2 by 8 inch pieces cut from all small bending-test specimens. These pieces were set upright on the weighing platform of the testing machine and crushed endwise. Observations of load and deflection were recorded as in the bending tests. From the data recorded the following factors were calculated in terms of pounds per square inch: Crushing strength at elastic limit, crushing strength at maximum load, and modulus of elasticity.

TABLE 1.—*Average values for green and air-seasoned material in each size tested, with ratios of strength values of air-seasoned material to those for green material.*

GREEN MATERIAL.

Cross section.	Bending.								Compression parallel to grain.						Compression perpendicular to grain.					Shearing.		
	Span.	Number of tests.	Moisture.	Rings per inch.	Fiber stress at elastic limit.	Modulus of rupture.	Modulus of elasticity.	Calculated shear.	Size of specimen.	Number of tests.	Moisture.	Crushing strength at elastic limit.	Modulus of elasticity.	Crushing strength at maximum load.	Stress area.	Height.	Number of tests.	Moisture.	Crushing strength at elastic limit.	Number of tests.	Moisture.	Shearing strength.
Inches.	*In.*		*Per cent.*	*No.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*	*1,000 lbs. per sq. in.*	*Lbs. per sq. in.*	*Inches.*		*Per cent.*	*Lbs. per sq. in.*	*1,000 lbs. per sq. in.*	*Lbs. per sq. in.*	*Inches.*	*In.*		*Per cent.*	*Lbs. per sq. in.*		*Per cent.*	*Lbs. per sq. in.*
8 by 16	180	14	86.5	19.9	3,734	4,492	1,016	300	6 by 6	36	83.4	3,146	1,240	3,865	6 by 8	16	13	86.7	473	140	82.5	740
6 by 12	180	14	87.3	17.8	3,787	4,451	1,068	224	2 by 2	145	75.8	3,476	1,153	3,954	6 by 6	12	14	83.0	424	.....	.....	.....
7 by 9	180	14	79.8	16.7	4,412	5,279	1,256	199	.....	.....	.....	.....	.....	.....	6 by 7	9	13	74.7	477	.....	.....	.....
3 by 14	180	13	86.1	23.7	3,506	4,364	947	255	.....	.....	.....	.....	.....	.....	6 by 3	14	13	75.6	411	.....	.....	.....
2 by 12	180	12	70.9	18.6	3,100	3,753	1,052	187	.....	.....	.....	.....	.....	.....	6 by 2	12	12	66.5	430	.....	.....	.....
2 by 10	180	13	55.8	20.0	3,285	4,079	1,107	169	.....	.....	.....	.....	.....	.....	6 by 2	10	11	55.0	423	.....	.....	.....
2 by 8	180	13	63.8	21.5	2,989	4,063	1,141	134	.....	.....	.....	.....	.....	.....	6 by 2	8	12	56.7	396	.....	.....	.....
2 by 2	28	157	75.5	19.1	4,750	6,980	1,061	248	.....	.....	.....	.....	.....	.....	2 by 2	2	186	75.5	569	.....	.....	.....
AIR-SEASONED MATERIAL.																						
8 by 16	180	6	26.3	22.4	3,797	4,428	1,107	294	6 by 6	16	17.8	.....	.....	4,232	6 by 8	16	5	25.4	548	115	1.28	722
6 by 12	180	6	16.1	17.7	3,175	3,353	728	167	2 by 2	150	15.6	.....	.....	5,059	6 by 6	12	6	14.7	610	.....	.....	.....
7 by 9	180	6	15.9	15.2	3,280	4,002	1,104	147	.....	.....	.....	.....	.....	.....	6 by 7	9	5	14.8	500	.....	.....	.....
3 by 14	180	6	13.1	24.4	.....	5,033	.....	291	.....	.....	.....	.....	.....	.....	6 by 3	14	2	12.6	470	.....	.....	.....
2 by 12	180	5	13.8	14.4	3,928	5,336	1,249	260	.....	.....	.....	.....	.....	.....	6 by 2	12	2	16.2	498	.....	.....	.....
2 by 10	180	5	13.8	24.8	3,757	4,606	1,198	186	.....	.....	.....	.....	.....	.....	6 by 2	10	4	14.3	511	.....	.....	.....
2 by 8	180	6	13.7	20.7	4,314	5,050	1,313	166	.....	.....	.....	.....	.....	.....	6 by 2	8	2	13.2	429	.....	.....	.....
2 by 2	28	131	15.2	18.9	4,858	7,822	1,146	279	.....	.....	.....	.....	.....	.....	2 by 2	2	145	13.8	564	.....	.....	.....
RATIO, AIR-SEASONED TO GREEN.																						
8 by 16	.....	.....	.....	.....	1.02	0.99	1.09	0.98	6 by 6	.....	.....	.....	.....	1.09	6 by 8	16	.....	.....	1.16	.....	.....	0.98
6 by 12	.....	.....	.....	.....	.84	.75	.68	.75	2 by 2	.....	.....	.....	.....	1.28	6 by 6	12	.....	.....	1.44	.....	.....	.....
7 by 9	.....	.....	.....	.....	.74	.76	.88	.74	.....	.....	.....	.....	.....	.....	6 by 7	9	.....	.....	1.05	.....	.....	.....
3 by 14	.....	.....	.....	.....	.....	1.15	.....	1.14	.....	.....	.....	.....	.....	.....	6 by 3	14	.....	.....	1.14	.....	.....	.....
2 by 12	.....	.....	.....	.....	1.27	1.42	1.19	1.39	.....	.....	.....	.....	.....	.....	6 by 2	12	.....	.....	1.16	.....	.....	.....
2 by 10	.....	.....	.....	.....	1.14	1.13	1.08	1.10	.....	.....	.....	.....	.....	.....	6 by 2	10	.....	.....	1.21	.....	.....	.....
2 by 8	.....	.....	.....	.....	1.44	1.24	1.15	1.24	.....	.....	.....	.....	.....	.....	6 by 2	8	.....	.....	1.08	.....	.....	.....
2 by 2	.....	.....	.....	.....	1.02	1.12	1.08	1.12	.....	.....	.....	.....	.....	.....	2 by 2	2	.....	.....	.99	.....	.....	.....

COMPRESSION PERPENDICULAR TO THE GRAIN.

In the tests for compression perpendicular to grain the specimens consisted of one 24-inch section from each stringer and joist and one 2 by 2 by 8 inch section from each of the small bending specimens. Tests on the stringer and joist specimens were made by placing the piece on its narrow face, on the weighing platform of the testing machine, with the grain parallel to the platform. The load was applied to a steel plate 6 inches wide. The 2-inch-wide specimens were similarly tested, except that the steel plate through which the load was applied was only 2 inches across instead of 6 inches. Corresponding observations of load and deflection or crushing were taken, up to the elastic limit. From the data recorded, the crushing strength at elastic limit was calculated for each test in pounds per square inch.

SHEARING.

The shearing tests were made on small, clear blocks with a projecting lip 2 by 2 inches in section. The blocks were held firmly and the lip sheared off parallel to the grain. The load required to shear off the lip was computed in pounds per square inch for each test.

TABLE 2.—*Relative strength of material from Mendocino County (Shipment A) and Humboldt County (Shipment B), green material.*

Materials.	Number of tests.	Weight per cubic foot (oven-dry).	Moisture.	Rings per inch.	Fiber stress at elastic limit.	Modulus of rupture.	Modulus of elasticity.	Calculated horizontal shear.
		Pounds.	*Per cent.*	*Number.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*	*1,000 lbs. per sq. in.*	*Lbs. per sq. in.*
8 by 16 inches—15-foot span:								
Shipment B	7	21.4	99.0	16.5	3,707	4,506	981	298
Shipment A	7	23.0	74.0	23.2	3,760	4,479	1,051	301
Ratio, Shipment B to Shipment A	.....	93.1	.....	71.2	98.6	100.5	93.2	99.1
6 by 12 inches—15-foot span:								
Shipment B	7	21.5	91.5	10.3	3,609	4,109	972	205
Shipment A	7	23.8	83.0	25.4	3,966	4,794	1,163	242
Ratio, Shipment B to Shipment A	.....	90.4	.....	40.6	91.0	85.7	83.5	84.7
7 by 9 inches—15-foot span:								
Shipment B	7	21.5	82.2	13.3	3,919	4,256	1,115	157
Shipment A	7	24.9	77.4	20.2	4,906	6,303	1,396	241
Ratio, Shipment B to Shipment A	.....	86.4	.....	65.8	79.8	67.5	79.9	65.2
3 by 14 inches—15-foot span:								
Shipment B	7	22.2	82.5	19.4	3,506	4,450	984	259
Shipment A	6	22.3	90.2	28.7	3,340	4,263	905	249
Ratio, Shipment B to Shipment A	.....	99.6	.....	67.7	104.9	104.3	108.7	104.0
2 by 12 inches—15-foot span:								
Shipment B	6	23.0	82.4	15.3	3,507	3,873	1,176	190
Shipment A	6	23.1	59.5	21.9	2,693	3,633	928	183
Ratio, Shipment B to Shipment A	.....	99.6	.....	69.9	130.2	106.6	126.7	103.8
2 by 10 inches—15-foot span:								
Shipment B	7	23.2	73.1	14.6	3,587	4,182	1,130	172
Shipment A	6	23.1	35.6	26.3	2,933	3,960	1,080	166
Ratio, Shipment B to Shipment A	.....	100.3	.....	55.5	122.4	105.7	104.6	103.5
2 by 8 inches—15-foot span:								
Shipment B	7	22.7	74.1	17.9	2,414	3,185	1,089	104
Shipment A	6	23.1	51.8	25.6	3,658	5,087	1,200	170
Ratio, Shipment B to Shipment A	.....	98.4	.....	70.0	66.1	62.7	90.8	61.2
2 by 2 inches—28-inch span:								
Shipment B	84	21.2	81.0	14.5	4,527	6,555	1,025	232
Shipment A	73	23.8	68.9	24.4	5,018	7,458	1,101	266
Ratio, Shipment B to Shipment A	.....	89.2	.....	59.5	90.3	87.8	93.1	87.2

TABLE 3.—*Results of individual tests on green stringers and joists.*

Size.	Reference No.	Moisture.	Dry weight per cubic foot.	Rings per inch.	Proportion of summerwood.	Proportion of sapwood.	Cross-section classification.	Modulus of rupture (per square inch).	Fiber stress at elastic limit (per square inch).	Modulus of elasticity (per square inch).	Horizontal shear (per square inch).	Number of knots.						Other defects.	Manner of failure.[1]	Apparent cause of failure.
												Vol. 1.		Vol. 2.		Vol. 3.				
												Less than 1½ inches.	1½ inches and over.	Less than 1½ inches.	1½ inches and over.	Less than 1½ inches.	1½ inches and over.			
Inches.		*P. cent.*	*Lbs.*	*No.*	*Per ct.*	*Per ct.*		*Lbs.*	*Lbs.*	*1,000 lbs.*	*Lbs.*									
8 by 16	1	89.9	22.4	29.4	44	0	1	6,610	4,900	1,188	446	....	....	1	1	9	1	.....	C. T.	None.
	2	66.3	24.9	27.5	30	0	1	5,660	4,510	1,348	383	1	....	....	1	1	....	.....	C. T.	None.
	3	116.1	20.8	20.3	36	0	3	5,180	4,600	1,010	348	1	....	4	5	14	11	.....	C. T.	Large knot on upper face.
	4	52.3	22.2	21.5	31	0	1	5,170	3,900	1,203	339	....	....	12	2	2	9	.....	C. T.	None.
	5	57.9	25.9	28.0	28	0	1	4,650	4,590	1,296	315	3	....	3	1	12	1	.....	T.	Large corner knot 50 inches from center.
	6	157.7	19.8	16.5	35	0	1	4,620	4,110	967	307	1	....	....	....	1	....	.....	C.T.	None.
	7	56.0	26.0	18.0	25	0	3	4,540	3,320	1,343	307	....	1	1	1	8	12	.....	S.	None.
	8	62.2	23.1	17.0	38	0	3	4,440	3,420	1,265	297	....	....	3	3	5	7	.....	S.	None.
	9	63.7	18.2	19.0	26	0	1	4,410	3,280	928	294	....	....	1	1	2	1	.....	C. T.	None.
	10	167.4	21.2	8.5	45	0	1	4,140	3,080	688	272	....	....	....	....	10	....	.....	T.	None.
	11	64.6	20.2	14.0	16	0	1	4,010	3,660	871	265	....	1	1	2	2	2	.....	C. T.	Large knot on upper face.
	12	74.2	22.0	27.3	36	0	1	4,000	3,610	607	268	....	....	....	....	2	2	.....	T.	None.
	13	121.0	23.5	8.5	31	0	1	3,530	3,410	861	229	....	2	....	1	6	6	.....	T.	None.
	14	61.8	20.9	22.6	33	0	2	1,930	1,880	645	129	2	1	....	4	7	7	.....	T.	Irregular grain caused by knot.
Average		86.5	22.2	19.9	32	....	....	4,492	3,734	1,016	300	....	....	....	....	....	....	.....		
6 by 12	15	65.9	28.5	36.0	43	0	3	5,970	4,290	1,285	303	....	1	1	5	19	15	.....	C. T. S.	None.
	16	143.2	22.5	17.3	34	0	1	5,850	5,130	1,345	294	....	....	....	....	....	....	.....	C. T.	None.
	17	91.1	23.0	11.0	36	0	2	5,520	4,340	1,148	279	....	....	1	....	1	....	.....	C. T.	None.
	18	64.0	24.5	10.0	23	0	2	5,460	4,890	1,283	278	1	1	1	1	5	2	.....	C. T.	None.
	19	75.1	22.0	22.0	31	0	1	4,360	4,610	1,057	245	....	....	....	....	....	....	.....	C. T.	None.
	20	214.8	20.3	8.9	28	0	1	4,320	4,210	1,131	236	....	....	....	....	2	....	.....	C. T.	None.
	21	59.6	28.1	24.3	36	0	1	4,710	3,770	1,572	239	3	....	2	2	14	8	.....	C. T.	None.
	22	69.8	21.5	39.7	27	0	1	4,580	3,710	1,128	232	....	....	....	2	6	2	.....	T.	None—brash failure.
	23	96.9	22.8	7.5	20	0	1	4,300	3,550	566	215	....	....	....	....	4	....	.....	T. S.	None.
	24	84.8	21.8	19.5	37	0	2	4,080	2,840	672	207	....	....	....	....	....	....	.....	T.	None—brash failure.
	25	82.9	22.1	18.7	32	0	3	3,510	3,410	1,084	177	....	....	9	1	20	11	.....	T. C.	None.
	26	60.0	21.0	16.0	14	0	1	2,990	2,650	746	148	....	....	....	....	3	15	.....	T.	Wavy grain 15 inches from center.
	27	65.5	18.0	9.9	12	0	1	2,970	2,940	933	145	....	2	....	1	1	3	.....	T.	Large knot 40 inches from center.
	28	48.0	20.7	9.0	14	0	4	2,700	2,680	998	135	1	1	9	3	24	17	.....	T. S.	Large knot 40 inches from center.
Average		87.3	22.6	17.8	28	....	....	4,451	3,787	1,068	224	....	....	....	....	....	....	.....		

7 by 9	29	48.2	30.6	24.8	41	0	1	9,760	6,750	2,222	407					2		C.T.S.	None.
	30	51.7	21.5	20.0	33	0	3	7,180	5,530	1,560	267	9		3	3	36	5	C.T.	None.
	31	94.3	28.3	20.3	36	7	1	6,920	5,710	1,432	260			2				C.T.	None.
	32	75.5	25.5	14.3	28	0	3	6,880	5,360	1,377	253			1	2	6	6	C.T.	None.
	33	57.1	22.3	28.0	14	0	1	6,100	4,820	1,306	226					2		Curl.	C.T.	None.
	34	66.3	22.6	19.5	30	0	3	5,750	4,000	1,070	212	2		6	5	25	3	C.T.	Large knot on top face near center.
	35	128.3	25.6	27.8	39	0	1	4,900	4,320	1,354	186							C.T.	None.
	36	61.8	21.8	7.0	12	0	1	4,630	4,380	1,106	171	2		4		31	7	C.T.	None.
	37	216.9	19.8	8.0	15	0	1	4,300	4,000	1,075	156					3	1	C.T.	None.
	38	50.3	22.5	12.0	13	0	3	3,830	3,780	1,143	141	5	1	2	4	30	16	T.	Large knot on bottom face 53 inches from center.
	39	52.6	21.7	15.0	22	0	1	3,710	3,550	1,172	136					1	2	T.	Cross grain.
	40	67.1	21.0	16.0	18	0	1	3,710	3,400	714	136	1	2			3	2	T.	Large knot on bottom face 50 inches from center.
	41	69.3	21.1	7.0	13	0	1	3,510	3,500	1,290	132		1	2	2	3	6	T.	Cross grain.
	42	77.6	16.9	14.5	21	0	1	2,730	2,670	759	103		1			1	2	T.	Irregular grain.
Average		79.8	23.2	16.7	24			5,279	4,412	1,256	199								
3 by 14	43	64.5	26.0	22.8	8	0	1	6,410	4,560	1,383	373	1				13	7	C.T.	None.
	44	51.2	27.3	31.4	32	0	1	6,000	4,430	1,312	353			1	1	24	5	Shake.	C.S.	None.
	45	58.8	23.5	32.8	14	0	1	5,730	3,950	1,258	339			2	1	1	3	C.T.	None.
	46	130.8	23.2	42.1	36	0	1	4,730	3,560	976	276			2	1	11	5	C.T.	Small knot on top face 20 inches from center.
	47	98.2	26.8	17.5	16	0	1	4,570	3,780	855	269					1		C.T.	None.
	48	70.4	19.9	15.5	10	0	2	4,180	3,630	994	239	1	2		1	5	6	C.T.	None.
	49	132.8	20.0	10.0	15	0	1	4,030	3,550	1,000	235			1	2	4	5	S.	None.
	50	63.2	17.6	29.5	8	0	1	4,000	2,860	697	231					2		C.T.	None.
	51	66.8	23.3	19.5	31	0	1	3,900	2,960	816	227			2		4	3	T.	None.
	52	139.2	21.5	38.1	37	0	1	3,890	3,610	982	228	1		4		73	3	Checks.	S.	None.
	53	74.2	17.1	15.7	25	0	1	3,620	2,870	696	211					1	1	C.T.S.	None.
	54	79.3	21.1	25.5	35	0	1	3,440	2,610	646	200					1	1	C.T.	None.
	55	89.6	21.7	7.8	12	0	1	2,230	2,210	702	128					3	6	S.	None.
Average		86.1	22.2	23.7	21			4,364	3,506	947	255								
2 by 12	56	38.5	25.5	31.5	9	0	1	5,710	5,270	1,602	279					6		C.	None.
	57	54.8	23.0	15.0	19	0	1	4,010	3,250	1,196	203		1		2	14	12	C.T.	None.
	58	41.1	20.8	16.3	32	0	2	3,900	2,990	983	198			2	2	1	4	C.S.	Large knot on top face 15 inches from center.
	59	88.6	25.5	17.3	39	0	2	3,810	2,500	1,128	191	1		3				T.	None—brash failure.
	60	124.3	17.2	10.5	12	0	1	3,790	3,150	1,042	188					29		C.	None.
	61	47.6	22.1	31.6	27	0	3	3,790	2,920	891	190			2	3	12	7	C.T.	Large knot on top face 15 inches from center.
	62	90.2	18.8	11.1	19	0	2	3,770	2,420	1,109	189	5	1	3	3	1	1	C.T.	Large corner knot 22 inches from center.
	63	48.9	27.6	34.2	29	0	1	3,680	2,910	537	186					1		T.	None—brash failure.
	64	77.7	20.0	7.0	12	0	2	3,360	3,270	1,037	165		1		2	6	3	C.T.	None.
	65	145.9	30.5	7.0	32	0	2	3,190	3,040	839	152					3	4	T.	None—brash failure.

[1] Letters indicate sequence and kind of failure; C. indicates compression, T. tension, and S. horizontal shear.

TABLE 3.—*Results of individual tests on green stringers and joists*—Continued.

Size.	Reference No.	Moisture.	Dry weight per cubic foot.	Rings per inch.	Proportion of summerwood.	Proportion of sapwood.	Cross-section classification.	Modulus of rupture (per square inch).	Fiber stress at elastic limit (per square inch).	Modulus of elasticity (per square inch).	Horizontal shear (per square inch).	Number of knots.						Other defects.	Manner of failure.[1]	Apparent cause of failure.
												Vol. 1.		Vol. 2.		Vol. 3.				
												Less than 1½ inches.	1½ inches and over.	Less than 1½ inches.	1½ inches and over.	Less than 1½ inches.	1½ inches and over.			
Inches.		*P. cent.*	*Lbs.*	*No.*	*Per ct.*	*Per ct.*		*Lbs.*	*Lbs.*	*1,000 lbs.*	*Lbs.*									
2 by 12.....	66	52.9	22.1	20.8	14	0	1	3,180	3,060	1,337	156	1	2	6	1	9	9	.....	T.....	Large corner knot 30 inches from center.
	67	40.7	23.7	20.7	30	0	1	2,850	2,420	919	145	1	4	1	3	13	15	.....	T.....	Large corner knot 21 inches from center.
Average..	.....	70.9	23.1	18.6	23	....	....	3,753	3,100	1,052	187	....	....	....	....	....	....	.....	.....	.....
2 by 10.....	68	39.1	25.6	22.5	14	0	1	6,510	5,170	1,584	273	....	....	....	....	2	....	.....	C.T....	None.
	69	81.5	24.6	22.0	10	0	2	5,200	4,390	1,304	212	....	....	....	....	20	....	.....	C.T....	None.
	70	54.3	27.6	32.3	32	0	2	5,190	4,090	1,456	217	....	....	1	2	3	1	.....	C.T....	Large knot on top face 28 inches from center.
	71	90.8	25.1	10.0	15	0	2	4,520	3,860	982	189	....	....	2	....	6	2	.....	C.T....	None.
	72	69.0	22.3	15.0	14	0	1	4,350	3,690	1,333	177	1	....	....	....	6	1	.....	C.T....	None.
	73	31.2	26.5	28.8	36	0	2	4,290	3,020	571	178	....	....	....	....	53	....	.....	C.....	None.
	74	38.6	20.7	26.5	37	0	1	4,080	3,070	1,019	174	....	....	....	....	8	8	.....	S.....	Checks.
	75	33.4	17.8	33.8	31	0	1	3,460	2,220	671	145	....	....	....	....	34	....	Shake..	C.....	None.
	76	27.6	21.8	18.3	30	0	2	3,380	3,260	1,121	140	....	....	6	2	9	4	.....	S.....	Checks.
	77	28.8	24.2	18.0	21	0	1	3,360	1,940	1,645	139	2	1	3	....	15	....	Checks..	S.....	Checks.
	78	94.2	22.8	7.0	25	0	1	3,150	2,900	671	128	....	....	....	....	2	4	.....	T.....	Irregular grain.
	79	72.1	21.1	15.0	17	0	2	2,940	2,550	947	121	....	....	....	1	3	3	.....	C.T....	None.
	80	64.8	20.7	11.0	12	0	1	2,600	2,550	1,088	105	1	2	1	1	3	14	.....	T.....	Large corner knot 48 inches from center.
Average..	.....	55.8	23.1	20.0	23	....	....	4,079	3,285	1,107	169	....	....	....	....	....	....	.....	.....	.....
2 by 8.....	81	41.7	24.8	35.0	39	0	1	6,530	4,100	1,364	222	....	....	3	....	10	2	.....	C.T....	Large corner knot 36 inches from center.
	82	32.6	25.4	18.3	42	0	2	5,840	4,450	1,557	198	....	....	10	1	10	2	.....	C.T....	Small corner knot at center.
	83	49.7	24.8	23.0	36	0	1	5,430	4,370	1,124	182	....	....	....	....	2	1	.....	C.T....	None.
	84	27.5	21.7	27.1	34	0	2	4,480	2,930	1,095	139	....	....	4	5	5	4	.....	T.C....	Bruise on lower face at center.
	85	117.3	23.6	34.4	50	0	2	4,380	3,360	1,345	147	....	....	....	....	3	2	.....	C.....	Small corner knot 10 inches from center.
	86	123.0	23.5	28.0	11	0	2	4,290	3,270	1,133	135	....	....	....	....	11	....	.....	C.T....	None.
	87	41.9	18.4	16.0	28	0	1	3,860	2,740	718	129	....	....	....	....	....	2	.....	C.T....	None.
	88	79.0	19.9	5.5	9	0	2	3,710	2,260	1,090	124	....	....	5	1	1	7	.....	C.T....	None.
	89	58.1	31.2	26.0	23	0	1	3,560	3,060	1,172	120	....	....	....	....	7	1	.....	T.....	None.

	90	63.8	18.0	20.0	11	0	2	3,520	2,880	751	113	....	....	....	....	1	....	.....	T.....	None.
	91	59.6	27.3	31.5	15	0	2	3,030	2,040	1,502	100	2	1	2	2	12	3	.....	T.....	Large corner knot 481 nches from center.
	92	70.6	16.8	7.0	8	0	1	2,700	2,280	971	87	....	1	....	1	....	1	.....	C. T....	None.
	93	64.4	22.3	7.5	10	0	1	1,483	1,111	1,006	47	1	1	1	3	15	7	.....	T.....	Small corner knot 6 inches from center.
Average.	.....	63.8	22.9	21.5	24	.....	....	4,063	2,989	1,141	134	....	....	....	....	....	....	.....	.....	

TABLE 4.—*Results of individual tests on air-seasoned stringers and joists.*

Size.	Reference number.	Months seasoned.	Moisture.	Dry weight per cubic foot.	Rings per inch.	Sap.	Cross-section classification.	Modulus of rupture (per square inch).	Fiber stress at elastic limit (per square inch).	Modulus of elasticity (per square inch).	Horizontal shear (per square inch).	Knots. Vol. 1. Less than 1½ inches.	Knots. Vol. 1. 1½ inches and over.	Knots. Vol. 2. Less than 1½ inches.	Knots. Vol. 2. 1½ inches and over.	Knots. Vol. 3. Less than 1½ inches.	Knots. Vol. 3. 1½ inches and over.	Other defects.	Manner of failure.[1]	Apparent cause of failure.
Inches.			*Per ct.*	*Lbs.*	*No.*	*P.ct.*		*Lbs.*	*Lbs.*	*1,000 lbs.*	*Lbs.*									
8 by 16.....	1	24	56.3	23.3	20.8	0	1	6,320	.....	.....	423	....	....	....	....	....	....	.....	C. T.....	None.
	2	24	29.0	24.3	18.9	0	1	5,720	4,546	1,154	380	....	....	....	....	....	....	.....	T. C.....	None.
	3	42	16.8	23.2	17.1	0	3	4,930	3,240	1,347	321	1	....	3	1	11	5	.....	T.....	None.
	4	24	17.4	18.9	20.2	0	1	4,580	3,610	820	310	....	....	4	....	12	4	.....	C. T. S..	None.
	5	42	16.7	17.4	21.2	0	1	2,870	.....	.....	191	....	....	....	2	2	5	.....	C. S.....	None.
	6	42	21.6	22.6	36.5	0	3	2,150	.....	.....	142	3	1	3	4	6	4	.....	T.....	Irregular grain caused by knot 56 inches from center.
Average..	.....	....	26.3	21.6	22.4	.....	....	4,428	3,797	1,107	294									
6 by 12.....	7	24	19.3	22.7	20.5	0	1	4,990	4,210	977	255	....	....	....	....	....	....	.....	T.....	None.
	8	42	15.2	25.0	23.6	0	1	3,820	3,180	527	191	....	....	....	....	....	....	.....	T.....	None.
	9	42	14.6	15.8	15.6	0	1	3,040	2,890	732	151	....	....	....	....	....	2	.....	T.....	None.
	10	24	15.7	21.1	14.2	0	1	2,980	.....	.....	147	....	....	....	....	3	3	.....	T.....	None.
	11	42	16.0	24.2	23.8	1	3	2,700	2,420	674	134	....	....	17	1	5	3	.....	T.....	None.
	12	24	15.8	19.5	8.4	0	1	2,590	.....	.....	125	2	2	1	2	5	....	.....	T.....	Small knot on lower face 31 inches from center.
Average..	.....	....	16.1	21.4	17.7	.....	....	3,353	3,175	728	167									
7 by 9.....	13	42	15.5	22.9	16.7	0	1	5,480	4,560	1,068	206	....	....	1	3	8	1	.....	T. C.....	None.
	14	42	15.3	26.8	17.7	0	1	4,590	.....	.....	184	....	....	....	....	....	....	.....	S. T. C..	None.
	15	42	15.4	24.8	25.4	0	1	4,750	.....	.....	176	....	....	....	....	2	....	.....	T.....	None.
	16	24	15.8	17.3	6.1	0	1	3,320	.....	.....	121	....	....	....	....	....	....	.....	T.....	None.
	17	24	14.8	18.4	9.0	0	1	2,850	.....	.....	101	1	....	8	1	11	....	.....	T.....	None.
	18	24	18.6	21.4	16.4	0	1	2,660	2,000	1,140	96	....	1	1	2	9	6	.....	T.....	Irregular grain caused by knot 22 inches from center.
Average..	.....	....	15.9	21.9	15.2	.....	....	4,002	3,280	1,104	147									

[1] Letters indicate sequence and kind of failure; C. indicates compression, T. tension, and S. horizontal shear.

TABLE 4.—*Results of individual tests on air-seasoned stringers and joists*—Continued.

Size.	Reference number.	Months seasoned.	Moisture.	Dry weight per cubic foot.	Rings per inch.	Sap.	Cross-section classification.	Modulus of rupture (per square inch).	Fiber stress at elastic limit (per square inch).	Modulus of elasticity (per square inch).	Horizontal shear (per square inch).	Knots. Vol. 1. Less than 1¼ inches.	Knots. Vol. 1. 1¼ inches and over.	Knots. Vol. 2. Less than 1½ inches.	Knots. Vol. 2. 1½ inches and over.	Knots. Vol. 3. Less than 1½ inches.	Knots. Vol. 3. 1½ inches and over.	Other defects.	Manner of failure.[1]	Apparent cause of failure.
Inches.			*Per ct.*	*Lbs.*	*No.*	*P. ct.*		*Lbs.*	*Lbs.*	*1,000 lbs.*	*Lbs.*									
3 by 14	19	24	12.9	30.0	31.0	0	1	6,530	.....	.....	374	.....	.....	1	.....	.....	.....	.....	T.	None.
	20	42	12.9	24.5	23.3	0	1	5,280	.....	.....	306	2	.....	1	.....	18	.....	.....	T.	None.
	21	42	13.5	25.8	23.4	0	1	5,220	.....	.....	305	.....	.....	.....	.....	15	1	Checks..	S. C. T..	None.
	22	24	13.1	22.3	16.9	0	1	4,520	.....	.....	261	1	1	1	1	5	8	.....	T.	Large corner knot 37 inches from center.
	23	24	13.7	26.2	24.9	0	1	4,370	.....	.....	252	1	1	.....	.....	9	.....	Checks..	S. T.	Cheeks.
	24	42	12.6	22.8	27.2	0	1	4,280	.....	.....	247	.....	1	2	1	9	10	.....	S.	None.
Average..	.....	....	13.1	25.3	24.4	.....	....	5,033	.....	.....	291									
2 by 12	25	23	15.5	32.8	14.0	0	1	7,230	4,810	1,303	359	.....	.....	.....	1	4	.....	.....	T.	None.
	26	24	12.5	20.7	15.7	0	1	5,320	3,340	1,272	254	1	.....	2	.....	11	7	.....	T. C.	None.
	27	23	15.7	22.4	15.0	0	1	5,050	4,150	1,504	246	.....	.....	2	.....	3	2	.....	T.	None.
	28	24	13.1	22.5	10.2	0	1	4,590	.....	.....	224	.....	.....	.....	.....	2	.....	.....	T.	None.
	29	24	12.2	19.8	17.2	0	2	4,490	3,410	918	217	.....	.....	1	.....	.....	1	.....	T.	None.
Average..	.....	....	13.8	23.6	14.4	.....	....	5,336	3,928	1,249	260									
2 by 10	30	24	12.6	25.9	24.5	0	2	6,140	.....	.....	247	.....	.....	.....	.....	.....	.....	.....	T.	None.
	31	24	12.3	20.6	8.5	0	2	5,000	3,110	1,245	200	.....	.....	6	.....	14	3	.....	T.	None.
	32	23	16.1	24.7	50.0	0	1	4,840	4,690	1,651	194	.....	.....	1	.....	8	2	.....	S.	None.
	33	23	15.7	24.0	24.0	0	1	3,950	3,470	698	162	.....	.....	.....	.....	.....	.....	.....	T.	None.
	34	24	12.4	21.0	17.0	0	2	3,100	.....	.....	126	.....	.....	6	.....	3	2	.....	S. C. T..	None.
Average..	.....	....	13.8	23.2	24.8	.....	....	4,606	3,757	1,198	186									
2 by 8	35	24	12.4	25.3	24.2	0	2	6,680	5,070	1,737	219	.....	.....	3	1	3	.....	.....	T. S.	None.
	36	24	12.4	22.7	8.1	0	2	5,950	4,210	1,189	192	.....	.....	1	.....	1	.....	.....	T.	None.
	37	23	15.0	21.4	17.0	0	2	5,080	3,570	1,292	172	1	.....	.....	.....	3	2	.....	T.	Irregular grain caused by knots.
	38	23	15.0	25.9	32.0	0	1	4,900	4,340	963	163	.....	.....	2	1	.....	1	.....	T.	None.
	39	23	15.3	24.4	28.0	0	2	4,800	4,380	1,385	157	.....	.....	.....	.....	.....	.....	.....	T.	None.
	40	24	12.0	22.2	15.0	0	2	2,890	.....	.....	94	2	.....	.....	3	6	5	.....	T.	Small knot on lower face 6 inches from center.
Average..	.....	....	13.7	23.6	20.7	.....	....	5,050	4,314	1,313	166									

[1] Letters indicate sequence and kind of failure; C. indicates compression, T. tension, and S. horizontal shear.

TABLE 5.—*Ratio of strength values of green redwood to those of green Douglas fir, with material of equal sizes.*

Bending.					Compression parallel to grain.		Compression perpendicular to grain.		Shear.
Size.	Fiber stress at elastic limit.	Modulus of rupture.	Modulus of elasticity.	Shear.	Size.	Crushing stress at maximum load.	Size.	Crushing stress at elastic limit.	Shearing strength.
Inches.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Inches.*	*Per cent.*		*Per cent.*	*Per cent.*
8 x 16	0.94	0.75	0.67	0.90	6 x 6	1.11	Large.	0.83	0.97
2 x 12	.83	.71	.64	.73	2 x 2	.99	.....	.....	.....
2 x 10	1.04	.87	.69	.89	.....	.....	.....	.....	.....
2 x 8	.83	.76	.71	.78	.....	.....	.....	.....	.....
2 x 2	.91	.84	.66	.74	.....	.....	.....	.....	.....

MOISTURE DETERMINATIONS.

Sections approximately 1 inch thick were cut from all of the specimens as soon as possible after they were tested. The sections were weighed and then dried to constant weight at 100° C. The difference between the original weight and the dry weight, divided by the dry weight, gives the percentage of moisture in the specimen at the time of test. In the stringers and joists an additional 1-inch section was taken from each piece. The pieces were cut into a number of portions, and the moisture content of each portion was determined separately in order to obtain a record of the distribution of moisture throughout the cross section. The parts of the cross sections in which the moisture contents were separately determined are shown in figure 1.

MISCELLANEOUS OBSERVATIONS.

All specimens were weighed and measured at the time of test. The average number of rings per inch, measured along a radial line, was computed, and the proportions of summerwood and of sapwood were recorded, as percentages. After the tests the specimens were either photographed or sketched to show the manner of failure and the location and size of defects.

DETERMINATION OF SEASONING.

In order to determine the rate of seasoning and its effect on the strength of the timber, 30 per cent of the pieces of each size were set aside to air season. The distribution of moisture in both green and air-seasoned material is indicated in figure 1. The quantities given in the diagram indicate the average moisture content as a percentage of the dry weight of the wood. On the pieces set aside for air seasoning, observations were made from time to time to determine their losses in weight and amounts of their shrinkage. The average results of these observations are shown in figure 2. In this diagram

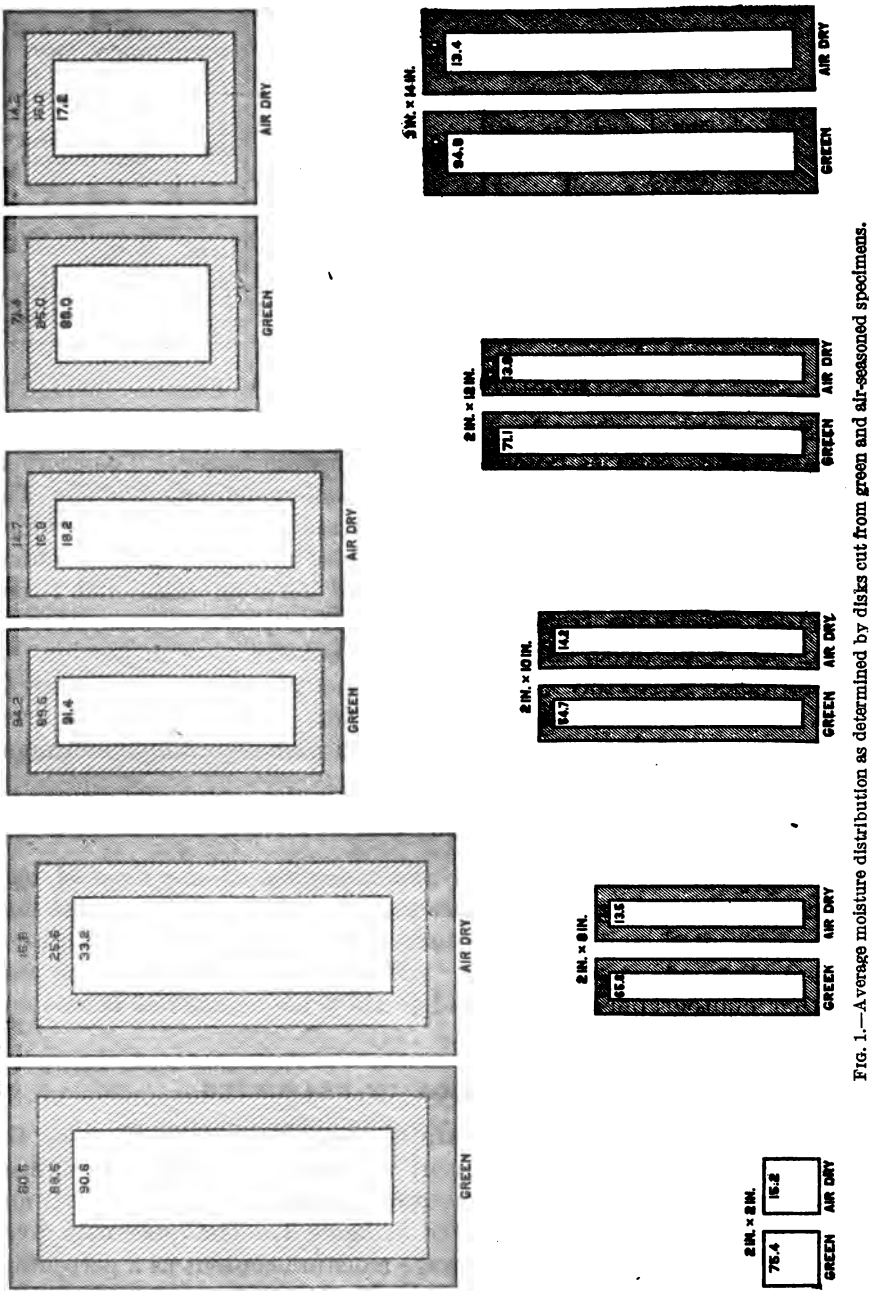

FIG. 1.—Average moisture distribution as determined by disks cut from green and air-seasoned specimens.

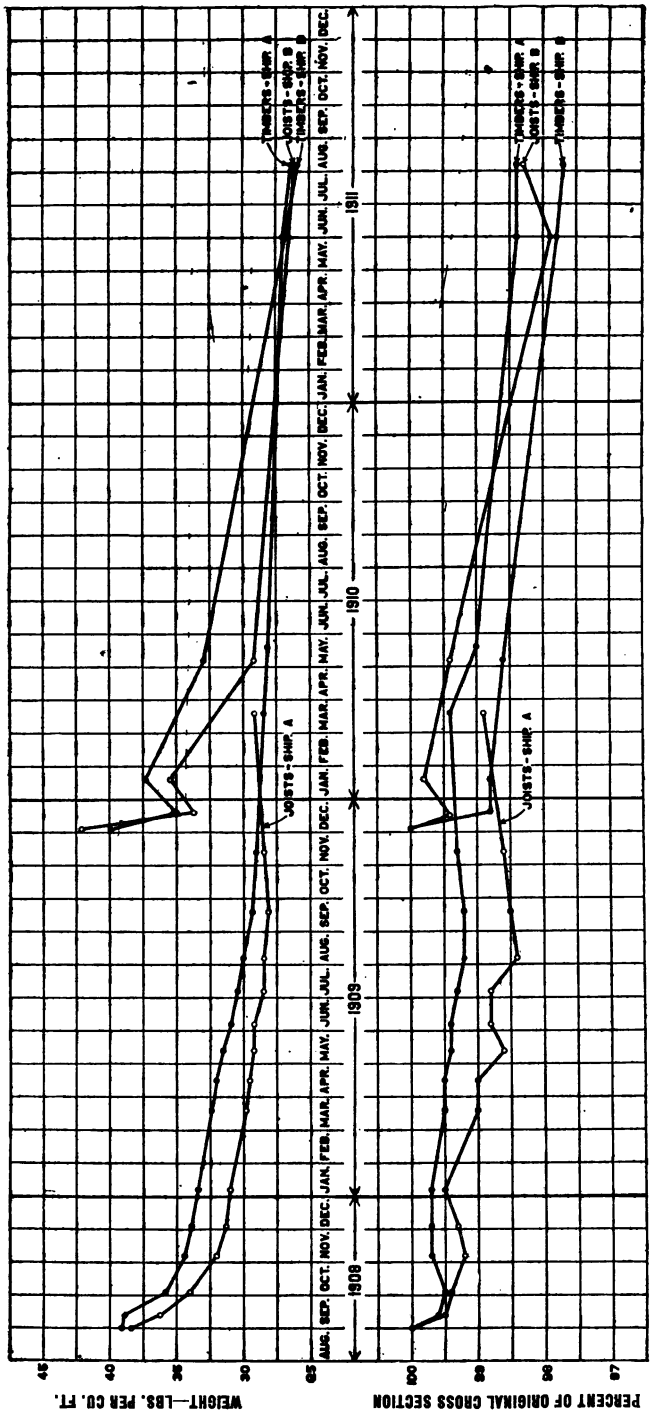

FIG. 2.—Loss in weight per cubic foot, and proportion of shrinkage in cross section due to seasoning.

the word "timbers" designates 8 by 16 inch, 6 by 12 inch, and 7 by 9 inch cross sections, and the word "joists" includes the four smaller sizes. The following general conclusions as to redwood are based on the data shown in figure 2:

1. Large timbers must season through two summers and joists through one summer before they reach a thoroughly air-seasoned condition.

2. Climatic conditions cause alternate evaporation and absorption of moisture. This is accompanied by corresponding shrinking and swelling of the surface portions of the timber.

3. The shrinkage factor for redwood is very low, although the wood contains a large amount of water when cut. The maximum moisture content was over 200 per cent and the average of the green pieces was about 75 per cent. During seasoning the average was reduced to about 16 per cent.

4. The low-shrinkage factor is an index of the fact that redwood can be seasoned easily without checking.

AVERAGE RESULTS OF TESTS.

Table 1 gives the average strength values for various sizes of both green and air-seasoned material, and the ratio of the strength values for air-seasoned material to the corresponding values for green material.

Small specimens, such as the 2 by 2 inch clear pieces, and even joists which are comparatively clear, show higher strength values for seasoned than for green material. In pieces larger than joist size, however, the increase in the strength due to seasoning is frequently more than offset by defects formed during the process. In other words, the strength of the piece as a whole may be decreased with seasoning. Because of this fact it is not advisable to count upon an increase in strength, due to seasoning, in the large pieces. It is safe to assume, however, that when large pieces are seasoned with reasonable care the working stresses for green material may be applied.

It will be seen from Table 1 that the shearing stresses which were actually developed in small, clear specimens are more than twice as high as the calculated shearing stresses for the bending tests. In the beam the actual area in resistance to shear is likely to be much less than that assumed in the formula because of checks, shakes, or other defects of a similar nature. The stringers which actually failed by longitudinal shear showed an average shearing strength of 302 pounds per square inch for green material.

In Table 2 the strength values of material of various sizes from Mendocino County (Shipment A) are compared with the strength values of similar material from Humboldt County (Shipment B).

The variation in strength between material from the two localities is no greater than can reasonably be expected between the individual pieces from one locality. The further analyses are therefore not kept separate.

Tables 3 and 4 give the results of individual tests, and from these results the tables for the principal bending tests were compiled. These can be used for the compilation of supplementary information.

Table 5 compares the strength of redwood and Douglas fir, as shown by Forest Service tests. In bending and compression at right angles to the grain redwood is about four-fifths as strong as Douglas fir, while in shearing strength and compression parallel to the grain for small, clear specimens the two species are practically equal. A large number of compression tests made by the University of California on specimens 4 inches square and 16 inches long gave an average value in compression parallel to the grain about 10 per cent greater for redwood than for Douglas fir.[1]

STRENGTH VALUES OF BEAMS AND SMALL PIECES.

In figure 3 the strength values, dry weight, and rate of growth are plotted for the individual beams of each size. The diagram was made by first plotting the solid line A, in which the values for modulus of rupture are arranged in order from the highest to the lowest. The other values (fiber stress at elastic limit, modulus of elasticity, dry weight per cubic foot, and rings per inch) were then plotted for each beam on the same vertical line as the modulus of rupture. The dotted lines indicate the average modulus of rupture and average crushing strength at maximum load of small clear specimens in comparison with the main test piece from which they were taken. It will be noted from this diagram that fiber stress at elastic limit, for the large bending specimens, and the crushing strength at maximum load, for the small specimens cut from them, bear a very close relation. This indicates that fiber stress at elastic limit is a measure of the quality of the wood fiber. The modulus of rupture, however, is influenced by all serious defects and is a measure of the quality of the beam as a whole. The more numerous and the more serious the defects, the closer the modulus of rupture approaches fiber stress at elastic limit.

[1] For comparison with other species see Bulletin 108, Tests of Structural Timbers.

TABLE 6.—*Variation of individual tests from the average; green material.*

Kind of test	Bending.									Compression parallel to grain.	Compression perpendicular to grain.	Shearing.
Kind of specimen	Stringers.			Joists.			Small, clear.			Small, clear.	Small, clear.	Small, clear.
Size of specimen	8 by 16 inches, 6 by 12 inches, and 7 by 9 inches, all 16 feet long.			3 by 14 inches, 2 by 12 inches, 2 by 10 inches, and 2 by 8 inches, all 16 feet long.			2 by 2 by 30 inches.			2 by 2 by 8 inches.	Stress area, 2 by 2 inches.	Shear area, 2 by 2 inches.
Strength factors	Modulus of rupture.	Fiber stress at elastic limit.	Modulus of elasticity.	Modulus of rupture.	Fiber stress at elastic limit.	Modulus of elasticity.	Modulus of rupture.	Fiber stress at elastic limit.	Modulus of elasticity.	Maximum crushing strength.	Crushing strength at elastic limit.	Shearing strength.
Number of tests	42	42	42	51	51	51	157	157	157	145	186	140
Average value, pounds per square inch	4,741	3,978	1,113,000	4,701	3,203	1,062,000	6,980	4,750	1,061,000	3,954	569	741
Per cent of total number of tests that fell above the average	41	45	54	38	43	47	45	46	52	44	38	50
Per cent of total number of tests that fell below the average	59	55	46	62	57	53	55	54	48	56	62	50
Distribution of individual tests with regard to the average, in per cent of total number of tests:												
Between 200 and 205 per cent of the average												
Between 195 and 200 per cent of the average												
Between 190 and 195 per cent of the average	1		1								1	
Between 185 and 190 per cent of the average												
Between 180 and 185 per cent of the average									1			
Between 175 and 180 per cent of the average											1	
Between 170 and 175 per cent of the average	1		1									
Between 165 and 170 per cent of the average											1	
Between 160 and 165 per cent of the average					2				1	1		
Between 155 and 160 per cent of the average	1	1		3			1	1			1	
Between 150 and 155 per cent of the average			1	1	2	3			1			1
Between 145 and 150 per cent of the average	4			2		3			2	1	1	
Between 140 and 145 per cent of the average	3	2	2	5	2	2	2	1	1		1	
Between 135 and 140 per cent of the average	1	3	1	2	6	2	2	1	2	2	2	1
Between 130 and 135 per cent of the average	1	2	1	2	2	2	3	3	4	2	1	2
Between 125 and 130 per cent of the average	4	2	2	3	3	3	2	5	4	2	3	1

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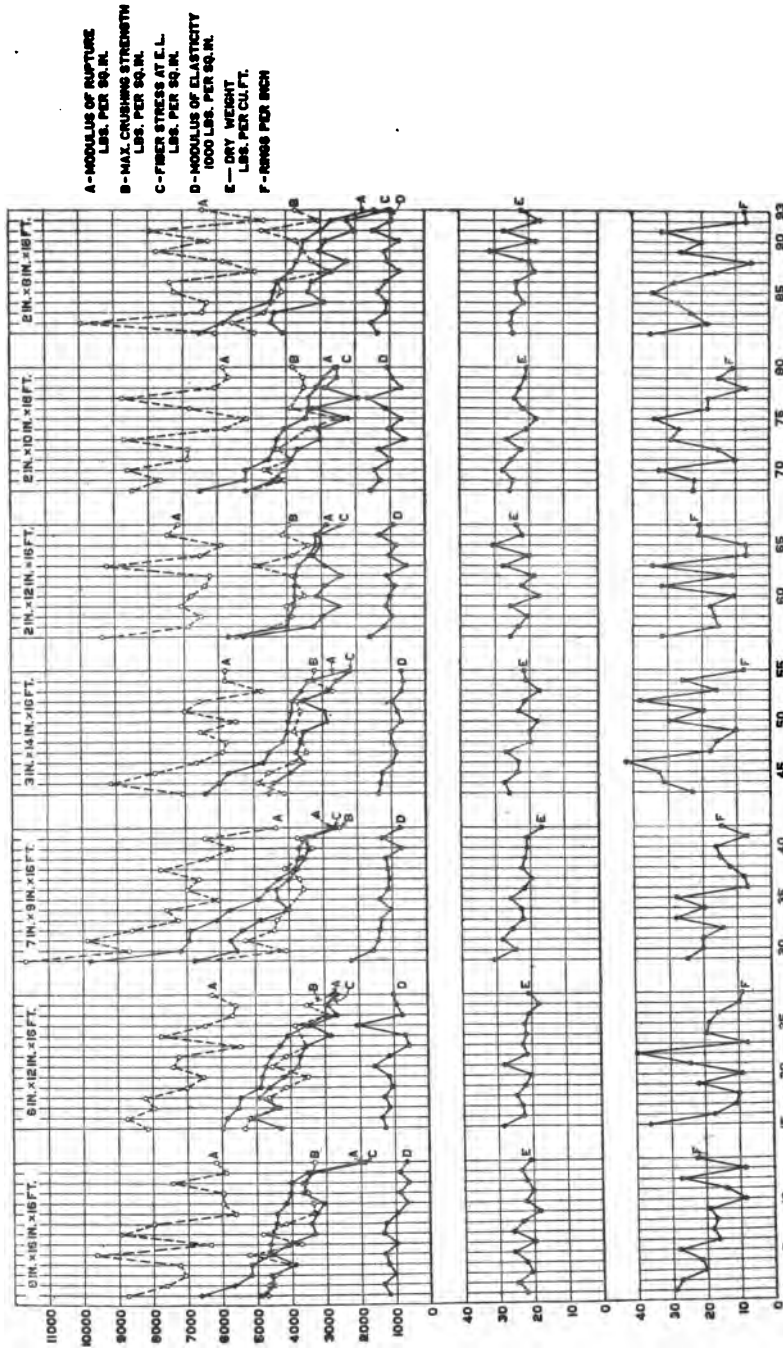

FIG. 3.—Strength values, dry weight per cubic foot, and rings per inch of green stringers and joists, and strength values of minor specimens cut from them.

VARIATION OF INDIVIDUAL RESULTS.

Average results in a material as nonhomogeneous as timber are of general significance only; unless the relation of the individual results to the averages is available, the averages may create an entirely erroneous impression.

Table 6 shows how the individual tests of the different classes vary from the averages given in Table 1.

The upper part of the table gives general data on the different classes of tests, while the lower part shows the distribution of the individual tests of each class above and below the average, which is indicated by the heavy line.

The proportion of the total number of tests which fell within certain limits indicated by the scale at the left of the table is shown by the figures in the columns. For example, under "Modulus of rupture for stringers," 5 per cent of the total number of stringers fell between 115 and 120 per cent of the average value, and only 1 per cent between 180 and 205 per cent of the average. In general, with a greater number of tests, there will be a more uniform distribution above and below the average, a larger proportion near the average, and a more uniform diminution with the distance from the average. Without doubt, all the values shown in this table would be changed to some extent by additional tests, and the distribution indicated will assist the reader in judging whether the average value would be increased or decreased by a larger number of tests.

RELATION OF MECHANICAL TO PHYSICAL PROPERTIES.

Wood differs from concrete, steel, and other construction materials in that its structure is so variable. For this reason it is necessary, in the inspection of structural timber, to understand what certain physical properties indicate, so that weak timber may be excluded. The physical characteristics of redwood timber which can be readily determined are: Color of the wood; relative proportion of heartwood and sapwood; position of the pith in cross section; rate of growth as shown by size of rings; weight; and proportion of summerwood.

COLOR.

The color of the heartwood, varying in redwood from light cherry to dark mahogany, is produced by deposits of various materials resulting from the process of growth. The sapwood is free from these materials and is almost white. Ordinary variations in the color of the heartwood apparently do not affect the mechanical properties of the wood. However, the appearance of pockets of punky, almost black, wood at the base of the trunk indicates a form of decay called brown, butt, or pin rot. It starts in the inner rings of the heartwood and extends outward to the sap and sometimes into the sap. As a rule it does not extend upward over 10 or 15 feet.

PROPORTION OF HEARTWOOD AND SAPWOOD.

In lumbering redwood it is customary to remove the thick bark from the logs before hauling them to the mill. After being allowed to dry, this bark is burned as it lies by the logs, together with the brush and limbs. At the same time most of the sapwood is destroyed, so there is very little sapwood in market material.

POSITION OF PITH.

In many specifications for large timbers the position of the pith or heart of the tree is considered, and the term "boxheart" is used to indicate those having the heart within the beam. Figure 4 shows the method of classification adopted by the Forest Service to indicate the position of the pith. In general, this factor is significant

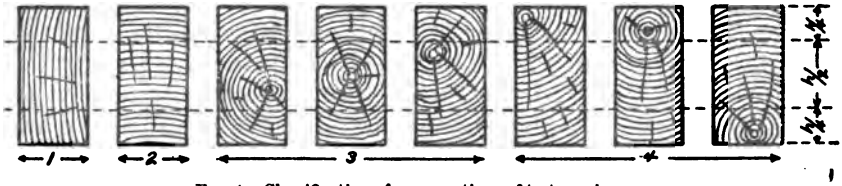

FIG. 4.—Classification of cross sections of test specimens.

1. Pith not in cross section. Rings vertical.
2. Pith not in cross section. Rings horizontal.
3. Pith within center half of cross section.
4. Pith within upper or lower quarter of cross section.

because of its relation to seasoning checks, which extend from the surface toward the pith. In class 3 the likelihood that checks will cause failures by horizontal shear is much greater than in any of the other positions of the pith. In redwood, however, the trees are so large that this class is not at all common; season checks are not numerous, and the relative position of the pith has little significance.

RATE OF GROWTH.

The rate of growth is determined by counting the annual rings intersecting a radial line of the cross section and dividing the number of rings by the length of the line in inches. Figure 5 shows the relation of rate of growth to modulus of rupture, to fiber stress at elastic limit, and to modulus of elasticity in small, green beams free from defects. It shows also the crushing strength at maximum load in compression parallel to the grain in small specimens cut from these beams. It appears from this diagram that the strongest wood is associated with a growth rate of about 30 rings per inch.

The individual points plotted for this diagram have a wide variation, and too much importance should not be attached to the relations shown, especially in commercial timbers containing defects. Figure 3 shows that there is no definite relation between strength

and rate of growth for large pieces with ordinary defects. Otherwise the curves showing rate of growth would bear a definite relation to the strength curves.

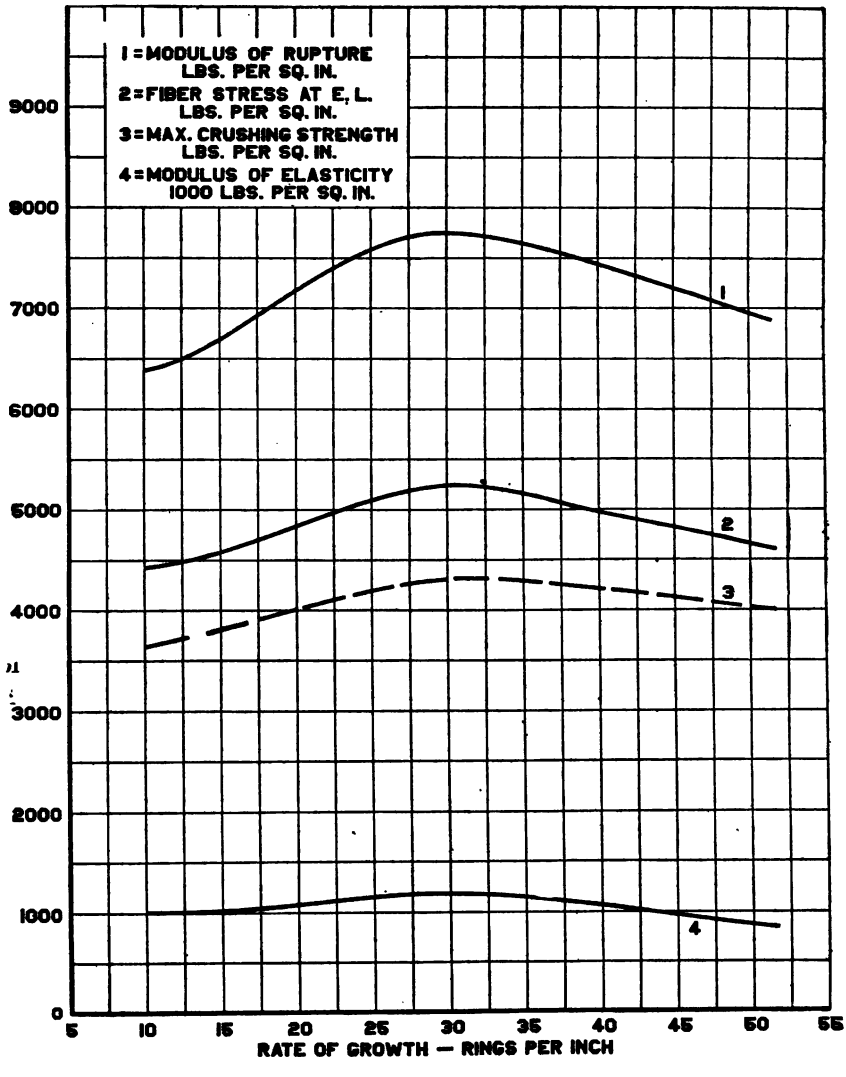

FIG. 5.—Relation of strength in bending and compression parallel to grain to rate of growth, as shown by the number of rings per inch; small, clear, green specimens.

WEIGHT.

Figure 6 shows the relation between the dry weight per cubic foot and the modulus of rupture, the fiber stress at elastic limit, and the modulus of elasticity for small, clear, green beams. It shows also the crushing strength at maximum load in compression parallel to

the grain in small specimens cut from them. This diagram confirms for redwood the conclusion which has been brought out for other species, that the mechanical properties of the clear wood vary directly with its dry weight. Reference to figure 3 shows how

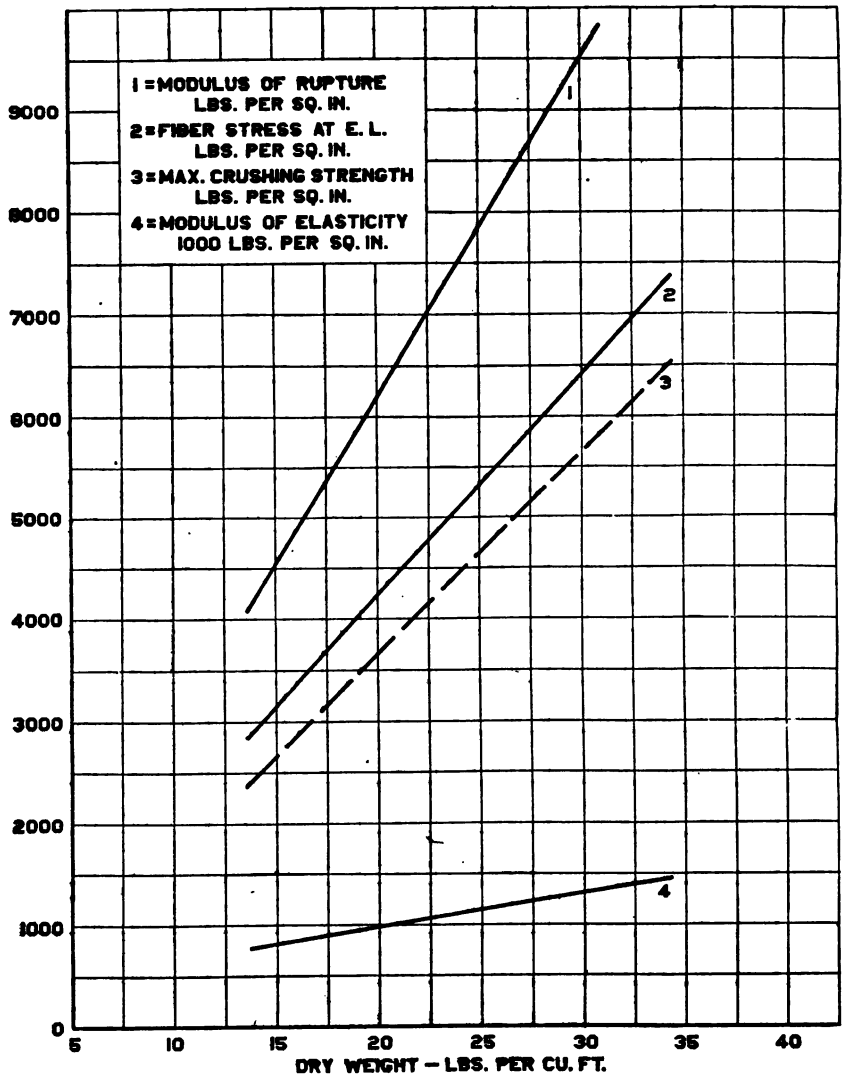

FIG. 6.—Relation of strength in bending and compression parallel to grain to dry weight per cubic foot; small, clear, green specimens.

this relation holds, and indicates a sharp drop in the modulus of rupture as the weight decreases. In structural timbers containing defects the relation between weight and strength will of course be influenced by the position and size of the defects.

PROPORTION OF SUMMERWOOD.

Summerwood is the term used to denote the dark, relatively dense portion of each annual ring. The light, porous portion is

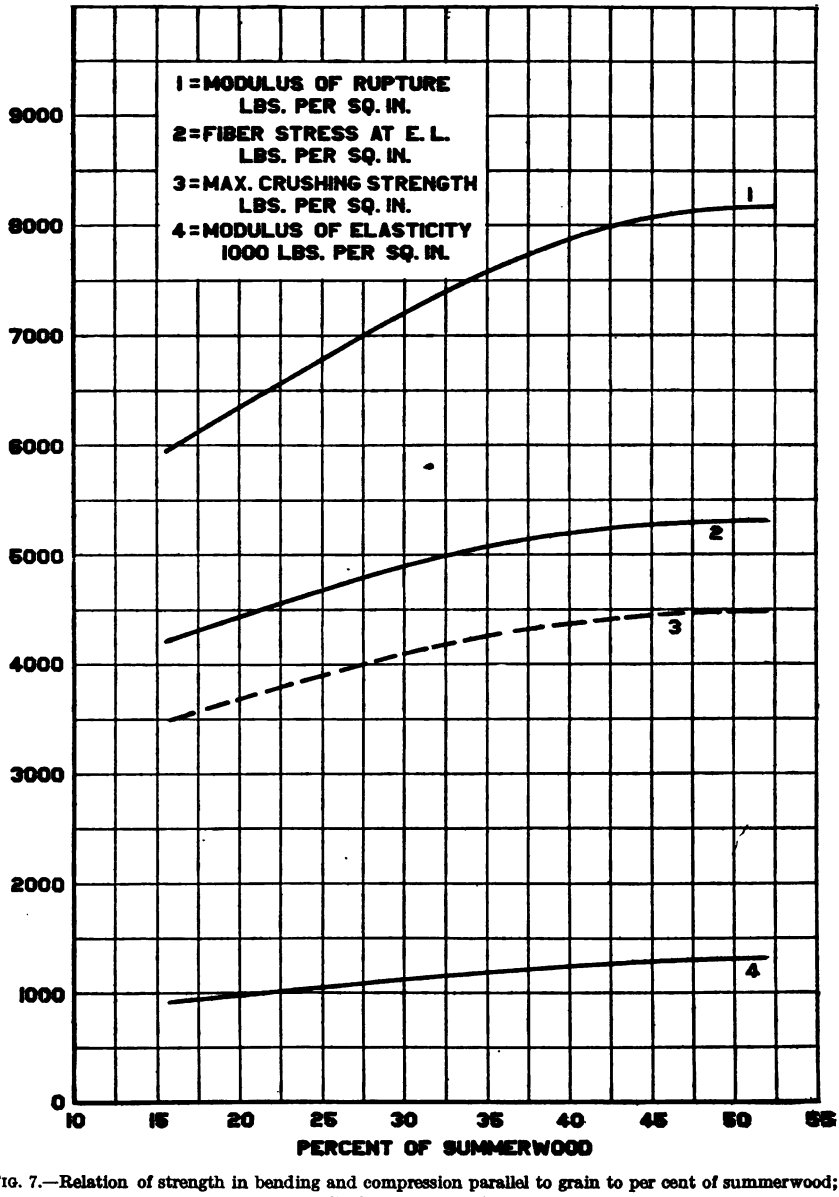

FIG. 7.—Relation of strength in bending and compression parallel to grain to per cent of summerwood; small, clear, green specimens.

termed "springwood." Summerwood is expressed as a percentage of the area of the cross section. Figure 7 shows the relation between the proportion of summerwood and the strength values in small,

clear, green specimens, tested in bending and compression parallel to the grain. In large pieces the proportion of summerwood is likely to vary, and the strength is so apt to be influenced by knots and other defects that in many timbers the proportion of summerwood is of little value in judging the strength. Nevertheless, the proportion of summerwood, independent of knots and other defects, is an important guide in judging the quality of redwood timbers.

FAILURES.

The failures of the redwood stringers and joists indicate the probable behavior of similar material. The results of the individual tests are contained in Tables 3 and 4.

These tests show, in the first place, that in all stringers, both green and air-seasoned, the proportion of first failures by horizontal shear was very low, since only 5 per cent of the green and 6 per cent of the air-seasoned pieces failed in this manner. In the green material 55 per cent failed first by compression and 40 per cent by tension. In the air-seasoned material 83 per cent failed first by tension and 11 per cent by compression.

In the stringers which failed first by tension, both green and air-seasoned, the greatest loss in strength is due apparently to irregular and cross grain. Such defects may or may not be associated with knots. The green stringers which failed by tension due to irregular or cross grain were only 63 per cent as strong as the average for all green stringers tested; the air-seasoned stringers so failing were only 51 per cent as strong as this average. The average strength of all stringers which failed first by tension was about three-quarters as great as the average strength of all green stringers.

As far as could be observed, only 13 per cent of the green stringers which failed first by compression, and none of the air-seasoned, were influenced by defects. The average strength of the green and air-seasoned stringers which failed first by compression was, respectively, 118 and 115 per cent of the average for all green stringers, and even those in which defects apparently influenced the failure were slightly above this average.

The few stringers which failed first by horizontal shear show a strength both for green and dry material practically the same as the average for all green stringers.

An examination of the calculated shearing strength in the stringers shows that in all cases, whether shear was the first failure or followed some other failure, or was not developed, the average calculated shear was higher in the green than in the dry specimens.

GRADING.

Because of the amount of clear material which may be had and the localized area of consumption, it has not been necessary to have the grading rules for redwood as specific as they are for some other species.

However, as redwood becomes better known, and as a wider distribution is secured, stricter rules for classifying the material will be necessary.

REDWOOD LUMBER MANUFACTURERS' RULES.

The grades in use by the redwood lumber manufacturers are as follows:

CLEAR REDWOOD.

Shall be good and sound, well manufactured, free from knots, shakes or splits, with the exception of season checks not to exceed 4 inches in length; will allow reasonable amount of birdseye and a fair proportion in each shipment may contain pin knots and small sound knots showing on one face only, and sap not exceeding 4 per cent of areas of all the surfaces, and slight variation in manufacture.

SURFACED CLEAR.

Shall be well manufactured and worked smoothly to uniform thickness. Will admit of slight roughness or variation in milling and defects mentioned under grade of clear.

SAP CLEAR.

Shall conform generally to the grade of clear, except that it may contain sap in excess of 4 per cent of the area of the surfaces. Will allow discoloration of sap.

COMMON.

Number 1 shall consist of lengths 10 feet and longer (except where otherwise specified) of sound lumber and free from such shakes, large or loose knots, or other defects that would materially impair its usefulness. Will allow slight variation in width and thickness. Sap not to exceed 4 per cent of the area of all the surfaces.

Number 2 shall consist of lengths 10 feet and longer (except where otherwise specified) free from splits extending more than one-sixth of its length. Will allow knots (sound or unsound), sap, shakes, and other defects which render it unfit for good, substantial construction purposes, but suitable for an inferior class of work.

STRIPS.

1 x 3, 4, and 6 inches.

Shall conform to above rules except that lengths shall be 10 feet and longer.

BOARDS.

Number 1 (8 inches and wider) shall be well sawed, 10 feet and longer, free from shakes and splits, admitting any number of sound knots less than 2½ inches in diameter and one knot, black or red, 2½ inches in diameter in each 5 superficial feet. Will allow slight variation in width and thickness. Sap not to exceed 4 per cent of the area of all surfaces.

Number 2. Will allow sap, loose and rotten knots, shakes, and other recognized defects which render it unfit for good, substantial construction purposes, but suitable for an inferior class of work. Also splits not extending over one-fourth the length of the piece.

STANDARD GRADE, RUSTIC STOCK.

Will allow three or four sound knots 1¼ inches in diameter. One or two sound knots between 1¼ and 2 inches in diameter. Sap with small knots. Poor machining, which would make it unfit for Clear.

Grain of all grades shall be as the lumber runs.

TENTATIVE GRADING RULES.

In Bulletin 108 of the Forest Service [1] a set of tentative grading rules for structural timbers is presented. It is the purpose of these rules to divide structural timbers, on a basis of the appearance of the individual pieces, into the following grades:

Grade 1.—Timbers having a modulus of rupture over 4,000 pounds per square inch.

Grade 2.—Serviceable timbers having a modulus of rupture under 4,000 pounds per square inch.

Culls.—Timbers having visible defects which render them unfit for structural purposes.

Application of these rules to redwood and eight other species gave a good strength classification in every case. It should be understood that these tentative rules are for the purpose of strength classification only and do not take into account requirements of a general nature such as conformity to dimensions, proportion of sap, or any other requirements which might be made necessary by peculiarities of certain species.

DEFINITIONS.

In the tentative rules which have been advanced a number of new definitions have been put forward.

Dense wood.—The term "dense wood" will be used to define the quality of wood which is desired in timbers subjected to stresses such as occur in frame structures. The term applies to the wood itself, irrespective of defects. Since dry weight, which is the most accurate index to the mechanical properties of wood, can not be determined from a casual inspection of the timber, dense, or, in other words, comparatively heavy wood will be defined as:

1. Wood that shows more than eight rings per inch, or which contains rings with more than 30 per cent summerwood.

2. Wood which is resilient; that is, wood which when struck with a hammer, or similar blunt instrument, gives a sharp, clear sound, while the hammer shows a marked tendency to rebound, and the wood a tendency to recover from the effects of the blow.

These properties are to be judged from an inspection of the cross section of the timber.

Knots.—Knots are portions of branches which have been encased in the growing trunk of the tree. In judging their effect upon the strength of timber it should be borne in mind that the axis of a knot always extends to the center or pith of the tree,[2] and that the visible part of the knot is a section of a somewhat conical mass of wood, the apex of the cone being at the pith of the tree, and the knot, as a whole,

[1] Tests of Structural Timbers, by McGarvey Cline and A. L. Heim.

[2] Exceptions to this rule are found where knots are caused by adventitious branches, but such exceptions are so rare that they can be ignored in the grading of structural timbers.

more or less intertwined with the wood surrounding it. A spike knot is a longitudinal section of a whole knot, and a round or elliptical knot is a section, respectively at right angles or at some oblique angle, to the axis of the knot. Sound knots, as a rule, are stronger and harder than the wood fiber surrounding them. Their effect, therefore, upon the strength of the timber depends to a large extent upon the manner in which they are connected to the surrounding wood and upon the degree of stress to which the connecting fibers are subjected. If the knots disturb the grain so that it is decidedly oblique to the edges of the timber, the wood will be subjected to stresses in tension at right angles to the grain, the kind to which it offers the least resistance. In such cases early failure in cross-grain tension almost invariably results.

Class 1 knots: Class 1 knots must be solid, firmly attached to the surrounding wood, and must cause no marked irregularity in the grain of the timber. Small spike knots will be included in this class.

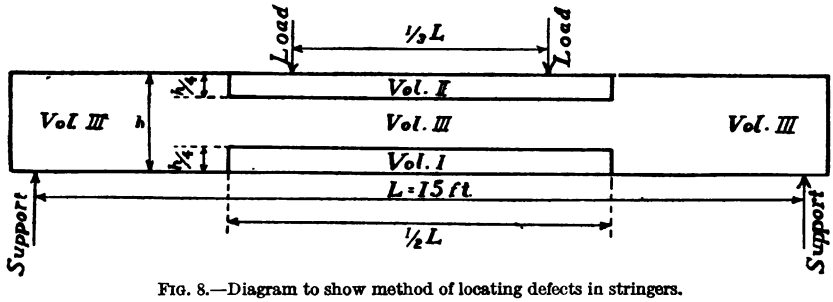

FIG. 8.—Diagram to show method of locating defects in stringers.

Class 2 knots: Class 2 knots must be solid, but are insecurely attached to the surrounding wood, or associated with burl or other irregularity in the grain.

Class 3 knots: Class 3 knots are unsound knots; that is, they are softer than the surrounding wood.

Dimensions of knots: The dimension of a knot on the narrow face of a timber will be the projection of the knot on a line perpendicular to an edge of the timber. On the wide, or vertical, faces the smallest diameter of a knot is to be taken as its dimension.

Small knots: Knots less than 1½ inches in diameter.

Large knots: Knots 1½ inches or more in diameter.

Position of defects.—The position of defects is designated by means of the three volumes indicated in figure 8.

TENTATIVE RULES FOR REDWOOD.

Grade 1 timbers.

(*a*) Must contain only dense wood.

(*b*) Must not have class 2 or large class 1 knots in volume 1.

(*c*) Must not have large class 2 knots in volume 2.

(*d*) The aggregate diameters of knots on any face within the center half of the length shall not exceed the width of the face.

(*e*) Must not have shakes or deep checks.

(*f*) Must not have diagonal grain with a slope greater than 1 inch in 20.

Grade 2 timbers.

(*a*) Must contain only dense wood.

(*b*) Must not have large class 2 knots in volume 1.

(*c*) The aggregate diameters of knots on any face in the center half of the length shall not exceed two times the width of the face.

(*d*) Must not have shakes which extend along an annual ring a distance greater than the width of the piece.

COMPARISON OF GRADING RULES.

Table 7 shows the results of applying the two grading rules to the 42 green redwood stringers tested. The lumber manufacturers' rules were applied to the pieces in accordance with their appearance before testing. The proposed tentative grading rules were applied through photographs and sketches of the pieces, which showed the size and location of defects. There was no opportunity in the latter case, therefore, to judge the resiliency of the timber, and only the defects were considered. Comparison of the results obtained from the two sets of specifications indicates that the tentative rules permit a larger proportion of material in the highest grade than the manufacturers' rules do; that the range in strength values for first-grade material is the same for both classifications; and that with the proposed rules those pieces ordinarily graded common, and which showed high strength values in test, fall in the best grade.

TABLE 7.—*Comparison of manufacturers' grading rules with the tentative rules.*

Grades.	No. of tests.	Modulus of rupture.	Fiber stress at elastic limit.	Modulus of elasticity.
		Pounds per square inch.	*Pounds per square inch.*	*1,000 pounds per square inch.*
All grades:				
Average	42	4,741	3,978	1,113
Maximum		9,760	6,750	2,222
Minimum		1,930	1,880	566
Lumber manufacturers' rules:				
Clear—				
Average	11	5,431	4,446	1,169
Maximum		9,760	6,750	2,222
Minimum		4,000	2,840	607
Common—				
Average	31	4,496	3,811	1,093
Maximum		7,180	5,530	1,572
Minimum		1,930	1,880	566
Proposed grading rules:				
Grade I—				
Average	29	5,088	4,202	1,163
Maximum		9,760	6,750	2,222
Minimum		4,000	2,840	566
Grade II—				
Average	13	3,469	3,157	928
Maximum		5,750	4,000	1,290
Minimum		1,930	1,880	645

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FOREST SERVICE—Circular 194.

HENRY S. GRAVES, Forester.

FOREST PRODUCTS LABORATORY SERIES.

PROGRESS REPORT ON WOOD-PAVING EXPERIMENTS IN MINNEAPOLIS.

By

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FOREST PRODUCTS LABORATORY.

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PROGRESS REPORT ON WOOD-PAVING EXPERIMENTS IN MINNEAPOLIS.

INTRODUCTION.

This circular gives the results obtained after four years of heavy traffic in a service test on wood paving blocks of various species laid in cooperation with the city of Minneapolis, Minn.

Acknowledgment for assistance rendered in this experiment is due especially to the city engineer department of the city of Minneapolis; the Republic Creosoting Co. and the Kettle River Co. (formerly the Kettle River Quarries Co.), both of Minneapolis; the John Week Lumber Co., of Stevens Point, Wis.; the Cloquet Lumber Co., Cloquet, Minn.; the Larson Lumber Co., of Bellingham, Wash.; and the Westside Lumber & Shingle Co., Portland, Oreg.

DESCRIPTION OF THE TEST.

The experimental pavement is described in Forest Service Circular 141,[1] as follows:

THE EXPERIMENTAL PAVEMENT.

To learn the results of actual service on a larger number of woods than the manufacturers seemed likely to try under the existing public prejudice against unproved woods, the Forest Service undertook arrangements for the laying of an experimental pavement, in which some of the untried woods should be laid with those already standard.

* * * * * * *

VARIABLES.

The variables in this experiment, by means of which it was desired to gain information upon the points respectively involved, were:

(1) Species of wood.
(2) Heartwood and sapwood.
(3) Length of blocks.
(4) Angle of courses.

SPECIES OF WOOD.

The woods used in the experiment were longleaf pine, Norway pine, tamarack, Douglas fir, western larch, white birch, and hemlock. The longleaf pine was included in order to provide a standard of comparison by which the behavior of the other woods could be judged, since it is the species most used in the United States. It was the purpose to lay equal amounts, approximately 15,000 feet b. m., of each wood, or, allowing for ordinary waste in manufacture, about 65 linear feet of pavement on a street 50

[1] Wood Paving in the United States, by C. L. Hill.

feet wide. Various circumstances, particularly a lack of knowledge on the part of some of the lumber companies of the peculiar requirements for paving stock, largely increased the waste in sawing the blocks and prevented the full area being laid with some of the woods. The shortage in these woods was made up by others of which larger amounts were obtainable. The distribution of the species, as laid, is shown in figure 3. [See fig. 1, this circular.]

HEARTWOOD VERSUS SAPWOOD.

The character of the blocks of the different woods used was as follows:

Approximately all heart: Longleaf pine, Douglas fir, and western larch.

Mixed heart and sap: Norway pine and tamarack.

Heartwood and sapwood indistinguishable: White birch and hemlock.

It was unnecessary to make separate classes for this condition within the separate species, since any difference in resistance between heartwood and sapwood would become manifest in an uneven wearing of the blocks, rather than in a greater total wear. Therefore this variable would not obscure the results affecting the separate species.

LENGTH OF BLOCKS.

The lengths of the blocks in the different species are as follows:

	Inches.
Longleaf pine, variable	6 to 10
Norway pine, variable	6 to 10
Tamarack, variable	6 to 10
Douglas fir, variable	6 to 10
Hemlock	6
Western larch, one-half	4
Western larch, one-half	6 and 8
White birch, one-half	4
White birch, one-half	6 and 8

The width and also the depth of all the blocks was 4 inches. The larch, birch, and hemlock were air-seasoned for several months before being used. Exact records of the time of seasoning of the other woods were not obtainable, but none of them were entirely green when used. Of the Douglas fir, a portion was from very rapidly grown stock, and it was feared that it would be so weak that it would not fairly represent the average of this timber. Therefore further separation on the basis of this factor was made for this wood, and the narrow-ringed and wide-ringed blocks were laid in separate portions of the pavement.

* * * * * * *

CONSTRUCTION OF THE PAVEMENT.

Nicollet Avenue, on which this pavement is laid, is 50 feet wide. There is practically no gradient. The street was so prepared as to give to the pavement a crown of 8 inches. The foundation was made of Portland cement concrete, composed of Portland cement, 1 part; sand, 3 parts; crushed limestone, 7 pars; and was 5 inches in thickness. Over this as soon as it was sufficiently set was spread a 1-inch cushion of sand. The surface of the sand was carefully trued to grade, and upon this foundation the blocks were laid, as shown in figure 3. [See fig. 1, this circular.]

The area of the avenue between Washington Street and Second Street was reserved for the several species to be compared, and these were laid all at the same angle, 67½° with the curb. North of Second Street one wood, Norway pine only, was laid, and on this area different angles were used for the courses, one portion being laid at 90° to the curb, another at 45°, and a third at 67½°. The relation of these areas will be seen from the figure.

The body of the pavement was laid with close joints, the pavement being driven moderately after every dozen or so courses. At each curb was left a 1-inch expansion joint, between which and the body of the pavement was one longitudinal course of blocks. As soon as the pavement was laid it was thoroughly rolled with a steam roller. The expansion joints, which had been left open until the pavement should be rolled and thoroughly settled, were then filled with sand nearly to the top. The body joints and the top of the expansion joints were filled with pitch, heated to about 300° F., which was thoroughly broomed in with steel brooms. A light top dressing of sharp sand completed the pavement. As soon as thorough setting of the concrete was assured traffic was admitted.

The blocks were treated at the plants of the two creosoting companies cooperating in the experiment under the specifications of the city of Minneapolis for wood block pavement which were in force during 1906.[1] In brief, these specifications require that wood blocks be treated by a straight-pressure treatment with 16 pounds per cubic foot of a coal-tar oil having a specific gravity of 1.09 at 20° C. However, the oil used in the treatment of the white birch and western larch blocks had a lower specific gravity than that specified. An impregnation of 20 pounds per cubic foot was therefore used in the case of these species in order to compensate as nearly as possible for the

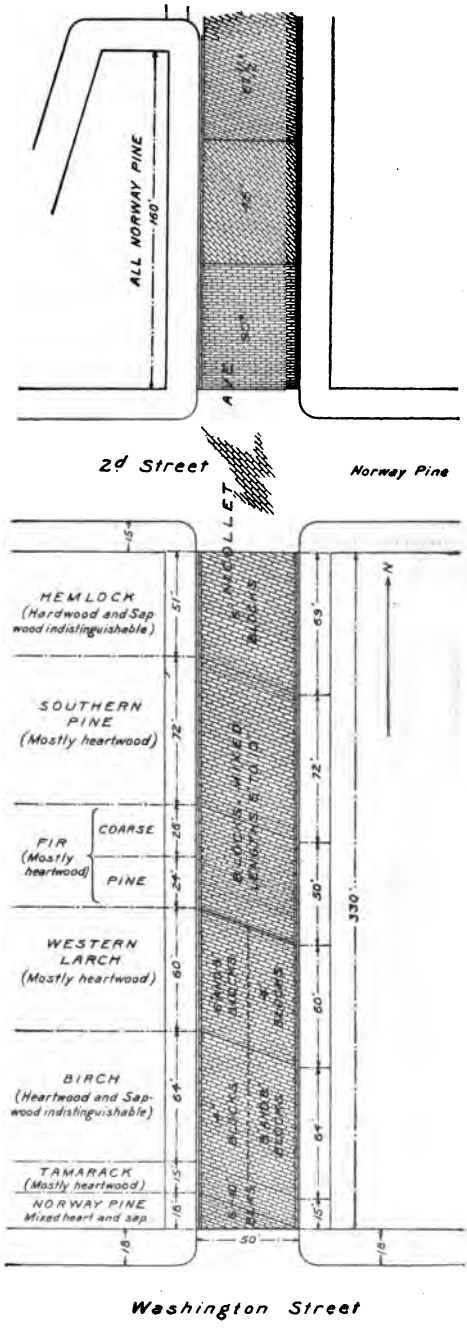

FIG. 1.—Experimental Creosoted Wood Block Pavement, Minneapolis, Minn.

[1] The specifications for paving oil of the city of Minneapolis for 1906, analyses of the oils actually used in the treatment of the experimental blocks, and records of the treatment are given on pages 12 and 13 of the Appendix.

discrepancy in specific gravity between the oil used and that specified.

At the time of inspection the city engineer department reported that since it had been laid the test pavement had been sprinkled with water six times per day during the sprinkling season and machine-swept each night. The department also reported that it was necessary to remove a few of the birch blocks which had failed from rotted heart, but that otherwise there had been no replacements.

Travel records of 12 hours' duration each were taken twice a month, a summary of which is given in Table 1.

TABLE 1.—*Summary of travel records taken on the experimental pavement.*[1]

	1906	1907	1908	1909	1910
Average tons per foot of roadway	127.17	132.02	149.15	143.52	154.23
Estimated 90 per cent of travel on middle 25 feet of roadway, average tons per foot	228.94	237.65	268.46	258.50	278.00

[1] Detailed travel records for 1906 and detailed summaries of travel records for succeeding years are given on pages 16-19 (includes Tables 6-10) of the Appendix.

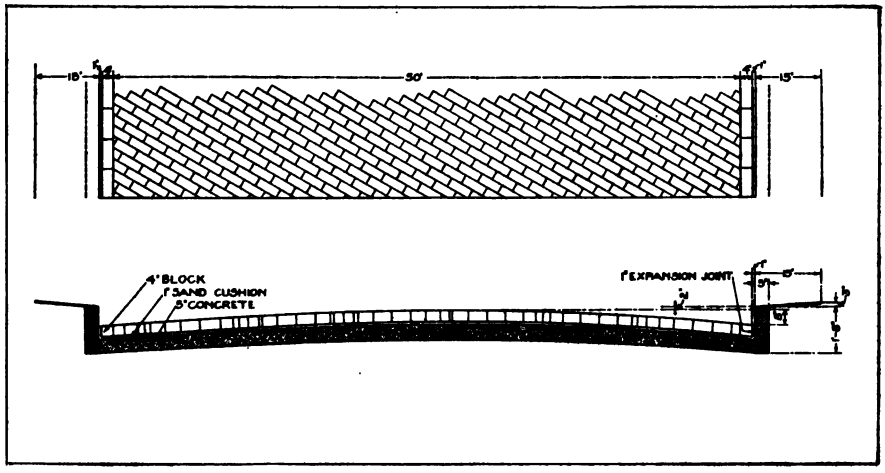

FIG. 2.—Construction of the experimental pavement.

METHOD OF INSPECTION.

The first formal inspection of the test pavement was made on August 17, 1910, by Mr. Ellis R. Dutton, assistant city engineer, city of Minneapolis, Mr. Frank Hussey, of the Kettle River Co., and the writer. The following observations were made:

(1) In each section one block of apparently average wear was removed from a position midway between the curb and the center of the street and a second block from near the curb. The two blocks were measured, and the difference in their heights was taken as the average wear of the section in question, the assumption being that

the blocks near the curb were not appreciably worn.[1] It was not thought best at the time of the inspection to remove a greater number of blocks from the general level of the sections. However, some additional blocks were removed from depressions.

(2) In order to obtain the approximate areas of holes in the pavement, each member of the party carefully estimated the total number of square feet of depression below the general surface in each section of the pavement. The estimates were averaged for each section, and these averages were taken as the areas of the depressions of the sections.

RESULTS OF INSPECTION.

Results of the inspection are given in Table 2. Since only two sections of the pavement were in a bad condition, no general conclusion can be drawn. However, a number of interesting points were observed, and the results of the inspection enable a tentative comparison of species to be made.

TABLE 2.—*Results of the first inspection of experimental pavement laid in Minneapolis, Minn., in 1906.*

Section No.	Species.	Area of section.	Original depth of block.	Depth of block of average wear for section.	Average wear of section.[1]	Area local depression one-half inch and less below general level of section.	Area local depression one-half inch and less below general level of section in per cent of total area of section.	Area local depression 3 inches to one-half inch below general level of section in per cent of total area of section.	Remarks.
		Sq. ft.	*Inches.*	*Inches.*	*Inches.*	*Sq. ft.*	*P. ct.*	*P. ct.*	
1	Norway pine.....	440	3 1/16	3 1/4	1/16	10	2.0	.....	All apparent depressions in one spot, possibly due to fire.
2	Tamarack.....	742	3 1/16	3 1/8	1/16	10	1.0	.....	
3	White birch (6 and 8 inch blocks)	1,609	3 1/16	3 1/8	1/16	8	.5	.....	About 40 to 50 blocks removed on account of decayed heart.
4	White birch (4-inch blocks).	1,615	3 1/16	3 1/8	1/16	10	.5	.....	Some blocks showed decayed heart.
5	Western larch (4-inch blocks).	1,505	3 1/16	3 1/2	1/16	33	2.0	.....	
6	Western larch (6 and 8 inch blocks).	1,497	3 1/16	3 7/16	1/8	55	3.5	.....	
7	Douglas fir.....	1,229	3 1/16	2 7/8	1 1/16	.....	30.0	35.0	Medium grain, 6 to 7 rings per inch.
8	.....do.....	1,293	3 1/16	2 7/8	1 1/16	.....	30.0	3.0	Coarse grain, 3 to 5 rings per inch.
9	Long leaf pine.....	3,583	3 1/16	3 3/4	1/8	17	.5	.....	
10	Eastern hemlock...	3,038	3 1/16	3 1/4	1/16	35	1.0	.....	

[1] Exclusive of local depressions below the general level of the section.

Sections 7 and 8 (coarse and medium grain Douglas fir) were so badly worn that the blocks had to be removed during the following

[1] Table 2 shows that the white birch and western larch blocks manufactured at Sandstone, Minn., had a depth of 3 1/16 inches, and that the blocks of other species manufactured in Minneapolis, were 3 1/16 inches in depth. While no records of the exact original depth of the blocks are available, it is recalled that the one lot of blocks was of slightly less depth than the other.

summer. The extreme depth of some of the depressions in the Douglas fir sections of the pavement requires some explanation, however, since the depth of depression does not in this case necessarily indicate the actual wear. Upon removal of several blocks from the lowest depressions it was found that the grain of the wood was no longer vertical but was inclined at a considerable angle, the blocks being separated into a number of pieces by longitudinal shear along the annual rings. This shearing and consequent inclination of the blocks must have taken place after the blocks had once become so reduced in depth by wear that their shearing strength could no longer resist the local tractive action to which they were subjected. The continual lessening of lateral support to the wood effected by wear and the continually increasing angle of inclination, of course, accelerated this action. The result is clearly shown in figure 3.

FIG. 3.—Badly worn Douglas fir paving block removed from a deep depression in the test pavement.

Since the Douglas fir was of rapid growth and poor grade, it is questionable whether the results of this test are a fair indication of its wearing qualities when used as a paving material.

Table 2 shows that the other blocks appear to have worn fairly uniformly. Sections 5 and 6 (western larch) show a greater average wear and also a larger percentage area of depression below the general level than the others. Section 9 (longleaf pine) shows the least average wear, and also presents a very uniform surface. Section 1 (Norway pine), section 2 (tamarack), and section 10 (eastern hemlock) showed equal average durability up to the time of the first inspection, and were only slightly below the longleaf pine; however, they showed a somewhat larger percentage of holes than the longleaf pine. The white birch, while showing little more wear and no more holes than the longleaf pine, had some replacement on account of heart rot. Since the Norway pine had all of its apparent depression

below the general level in one spot, it seems unlikely that this was caused by ordinary wear. On this account, also on account of the small area of the Norway pine section,[1] and because the rest of the section was very uniform, it is hardly fair to give percentage area of depression below the general level any weight in this case.

Until further results have been obtained from the test pavement, the species used may be tentatively grouped in accordance with the results of this inspection in the order of their value for creosoted paving material as follows:

1. Longleaf pine.
2. Norway pine, white birch, tamarack, eastern hemlock.
3. Western larch.
4. Douglas fir.

No more definite comparison of the species can be made until the blocks have remained in the pavement long enough to exhibit greater differences in wear.

At the time of the inspection the pavement was not examined for differences in wear due to mixed sapwood and heartwood, length of blocks, or angle of courses. However, at a later date an examination was made with these points in view, but no appreciable differences due to any of these variables were noted.

RELAYING THE ORIGINAL DOUGLAS FIR SECTIONS.

At the beginning of the summer of 1911, nearly five years after the laying of the test pavement, the Douglas fir blocks were in such bad condition that it was necessary to remove them from the street and relay this portion of the pavement. Figure 4 shows the general condition along the central portion of the street just before the relaying of the Douglas fir sections. In one spot, comprising an area of about 30 square feet (not shown in the figure), the blocks were so badly worn that they were completely shattered into small bits.

In view of the poor quality of the original Douglas fir blocks, it was decided further to test this species by relaying one of the worn-out sections of the pavement with a thoroughly good grade of Douglas fir. Accordingly, a quantity of grade A Douglas fir paving stock was procured for this purpose. It was the intention to replace the second worn-out section with a good grade of jack pine, but so much difficulty was encountered in procuring the timber that the plan was abandoned. Douglas fir blocks were laid over as much of the area to be repaved as the quantity secured would cover, and the remaining part was paved with the regular southern yellow-pine blocks then in use by the city and furnished by it.[2] The Douglas fir was furnished

[1] The Norway pine blocks laid for testing the angles of the courses are not considered in this comparison.

[2] The actual manufacture and treatment was done by the Republic Creosoting Co., but not, as in the case of the Douglas fir, without charge.

by the Westside Lumber & Shingle Co., of Portland, Oreg., and was manufactured into blocks and treated by the Republic Creosoting Co., of Minneapolis. The arrangement of the relaid sections, together with the original sections which were still in good condition at the time of the relaying, is shown in figure 3.

Both the Douglas fir and the southern yellow-pine blocks were practically all heartwood, straight grained, and of fairly uniform growth; the minimum average number of annual rings for any

FIG. 4.—General condition along the central portion of the street of the original Douglas fir blocks in the test pavement after 5 years' service.

single block being 9 for the Douglas fir and 6 for the southern yellow pine. The depth of the blocks of both species was $3\frac{15}{16}$ inches and the width approximately 4 inches. However, the Douglas fir blocks were all 8 inches in length, while the southern yellow-pine blocks varied in length from 5 to 10 inches, with an average length of 8 inches. The Douglas fir paving stock was seasoned approximately two months, and the southern yellow pine one month, before being manufactured into blocks. The latter operation preceded the treatment by only a few hours in each case.

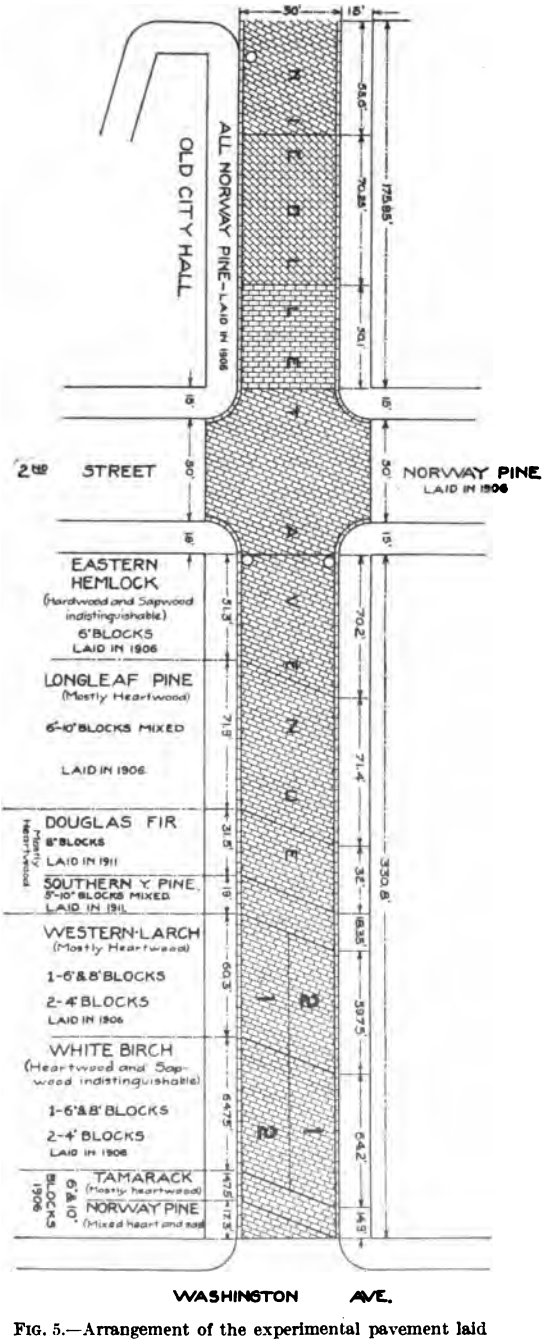

FIG. 5.—Arrangement of the experimental pavement laid in the summer of 1906; partially relaid June 27, 1911.

The blocks were treated at the Minneapolis plant of the Republic Creosoting Co. in two separate runs.[1] The Douglas fir blocks were treated with 17.9 pounds of creosote paving oil per cubic foot of wood; the specific gravity of this oil being 1.108 at 38° C. The southern yellow-pine blocks were treated with 17.3 pounds of a similar oil per cubic foot of wood.

The relaying of the pavement began June 27, 1911. It was noted that the old blocks from the middle of the pavement were so badly shattered that they fell apart into small chips as they were being taken up, although the blocks from near the curb came out practically whole. The sand cushion and the foundation were found to be in apparently perfect condition.

The foundation was scraped clean of the original sand cushion, and fresh, clean, practically gravel-free sand was spread over its surface. This new sand cushion was then surfaced off by a long metal-shod "straight-edge" which was drawn across the street, its two ends resting on 1-inch boards which were laid across the foundation and which served as "distance strips." This operation left a cushion of sand on the foundation 1 inch in thickness, the surface of which was further prepared by the use of a small hand scraper. The new blocks were then laid in the same manner as the original blocks, except that the former were driven only enough to keep the courses straight, and that the hot pitch filler was brushed into the body joints with a wooden scraper or "squeege" instead of with steel brooms.

The test pavement will continue to be under observation and care, and traffic records will be taken in the same manner as heretofore. Inspections will be made whenever they seem advisable.

APPENDIX.

SPECIFICATIONS OF THE CITY OF MINNEAPOLIS FOR WOOD-PAVING-BLOCK OIL FOR THE YEAR 1906.[2]

The specific gravity of the oil, at 20° C., shall be at least 1.09.

The oil shall be completely liquid at 25° C., and show no deposit on cooling to 22° C.

It shall not contain more than 2 per cent of water nor more than 3 per cent of matter insoluble in absolute alcohol or benzene.

Distillation test: One hundred grams of oil shall be placed in an 8-ounce retort, fitted with a thermometer, the bottom of whose bulb shall be placed one-half inch above the oil and not moved during the

[1] The specifications for paving oil of the city of Minneapolis, Minn., for 1911, the analyses of the oils used in the treatment of the experimental blocks, and records of the treatments are given on pages 13 and 14 of the Appendix.

[2] Reprinted from Forest Service Circular 141.

test. The discharge opening of the retort shall be from 20 to 24 inches from the bulb of the thermometer, and the retort shall be covered to prevent too rapid radiation. The percentages are for dry oil, and by weight:

Up to 150° C., nothing must come off.
Up to 170° C., 2 per cent.
Up to 210° C., from 6 per cent to 8 per cent.
Up to 235° C., from 20 per cent to 30 per cent.
Up to 315° C., from 40 per cent to 50 per cent.
Up to 355° C., from 60 per cent to 80 per cent.

Distillation shall be gradual and be completed, up to 315° C., in 30 minutes from the first drop, and entirely completed in 40 minutes.

TABLE 3.—*Analyses of the oils used in 1906 in the treatment of the paving blocks laid in the original test pavement.*[1]

	Birch treated at Sandstone, Minn., July 3, 1906.	Larch treated at Sandstone, Minn., July 5, 1906.	All others treated at Minneapolis: Fir, July 18, 1906; southern pine, July 1, 1906; hemlock, July 9, 1906.	Minneapolis specifications.
Specific gravity of oil at 20° C	1.07	1.07	1.09	1.09
Liquid at 22° to 25° C	Solid.	Solid.	Liquid.	Liquid.
Water per cent	5.20	5.20	2.30	2.00
Loss per cent up to 150° C	.05	.10	.40	0
Loss per cent up to 170° C	.37	.40	1.35	0 to 2
Loss per cent up to 210° C	5.82	5.36	7.90	6 to 8
Loss per cent up to 235° C	46.56	45.70	27.50	20 to 30
Loss per cent up to 315° C	72.91	72.28	59.60	40 to 50
Loss per cent up to 355° C	83.01	81.21	74.00	60 to 80

[1] From Annual Report of City Engineer City of Minneapolis, 1906.

TABLE 4.—*Record of the treatment of the paving blocks laid in the test pavement in 1906.*[1]

Species.	Square yards.	Treatment.		Pounds of creosote per cubic foot.
		Place.	Creosoting Co.	
White birch	358	Sandstone, Minn	Kettle River Quarries Co.	22.1
Western larch	333	do	do	20.4
Douglas fir	280	Minneapolis, Minn	Republic Creosoting Co	15.8
Eastern hemlock	338	do	do	15.5
Longleaf pine	398	do	do	18.5
Tamarack	335	do	do	16.2
Norway pine	4,213	do	do	16.0

[1] From Annual Report of City Engineer City of Minneapolis, 1906.

SPECIFICATIONS OF THE CITY OF MINNEAPOLIS FOR PAVING-BLOCK OIL FOR THE YEAR 1911.

The oil to be used in the treatment of the blocks shall be a pure heavy creosote oil, obtained from coal tar only, and of the following quality, viz:

The specific gravity of the oil shall be at least 1.10 at a temperature of 38° C.

It shall be completely liquid at 25° C. and show no deposit on cooling to 22° C.

It shall not contain more than 3 per cent of matter insoluble by hot continuous extraction with benzol and chloroform.

It shall be subjected to a distillation test, as specified below, and shall conform to the following requirements: 100 grams of oil shall be placed in an 8-ounce retort fitted with a thermometer, the bottom of the bulb of which shall be placed one-half inch above the oil and not moved during the test. The discharge opening of the retort shall be from 20 to 24 inches from the bulb of the thermometer and the retort shall be covered so as to prevent too rapid radiation. The percentages are for dry oil and by weight. The average of a number of tests shall show a mean of those percentages, viz, up to—

150° C., nothing must come off.

170° C., from 0 per cent to 0.5 per cent.

210° C., from 2 per cent to 4 per cent.

235° C., from 6 per cent to 16 per cent.

355° C., from 40 per cent to 55 per cent.

The distillation shall be gradual, and should be fully completed in 40 minutes from the first drop. Thermometer readings to be corrected for emergent stem.

TABLE 5.—*Analyses of the oils used in 1911 in the treatment of the paving blocks used in the relaid sections of the test pavement.*

	Oil used in treatments.	Minneapolis specifications.
Specific gravity of oil at 38° C	1.108	1.10
Liquid at 22° to 25° C	Liquid	Liquid.
Loss per cent up to 180° C	3.4 (yellow oil and water)	0 to 0.5 up to 170° C.
Loss per cent up to 210° C	15.0 (yellow paste)	2 to 4
Loss per cent up to 235° C	30.8 (yellowish white, solid)	6 to 16
Loss per cent up to 355° C	65.2 (dark-brown oil)	40 to 55

Samples of oil were taken separately for the Douglas fir and southern yellow pine treatments. These were analysed by the Forest Service method and found to be identical; consequently only one analysis was made, using the retort as described in the Minneapolis specifications.

RECORD OF THE TREATMENT OF THE PAVING BLOCKS LAID IN THE TEST PAVEMENT IN 1911.

DOUGLAS FIR: REPUBLIC CREOSOTING CO., MINNEAPOLIS, JUNE 23, 1911.

Preliminary vacuum of 25 inches drawn in 24 minutes.

Oil admitted and pressure gradually applied for 50 minutes. Maximum pressure, 135 pounds per square inch. Temperature of cylinder

during pressure period, 180° F. Temperature of measuring tank during pressure period, 200° F.

Absorption, as measured by the float gauge of measuring tank, 6 inches, or 1,176 gallons.

Specific gravity of oil at 210° F. (temperature at which preliminary and final gauge readings were taken), 1.065.

Amount of wood in treatment, 7,000 feet b. m. or 583 cubic feet.

Absorption, 17.9 pounds oil per cubic foot of wood.

SOUTHERN YELLOW PINE: REPUBLIC CREOSOTING CO., MINNEAPOLIS, JUNE 24, 1911.

Preliminary steaming at 150° F. for 1 hour 7 minutes.

Preliminary vacuum of 25 inches for 42 minutes.

Oil admitted and pressure gradually applied for 1 hour 16 minutes. Maximum pressure, 140 pounds per square inch. Temperature of cylinder during pressure period, 180° F. Temperature of measuring tank during pressure period, 200° F.

Absorption, as measured by the float gauge of measuring tank, 11¾ inches, or 2,303 gallons.

Specific gravity of oil at 210° F. (temperature at which preliminary and final gauge readings were taken), 1.065.

Amount of wood in treatment, 1,180 cubic feet.

Absorption, 17.3 pounds oil per cubic foot of wood.

TRAVEL RECORDS.

The following travel records are taken from the annual reports of the city engineer, city of Minneapolis, Minn., for the years 1906, 1907, 1908, 1909, and 1910. The complete detailed travel records are given here only for the year 1906, since that is sufficient to indicate the manner in which the records were taken. However, detailed averages for each succeeding year are given.

TABLE 6.—*Records of travel on Nicollet Avenue between Washington Avenue and Second Street during part of 1906.*

[Street paved in 1906 with 4-inch creosoted blocks on 5-inch Portland cement concrete foundation. Width of roadway, 50 feet. Records taken from 6 a. m. to 6 p. m.]

Classification of travel.	Wednesday, Aug. 1, 1906. Temperature: Maximum, 84; minimum, 63; weather, partly cloudy; moisture, none; condition of pavement, dry.		Thursday, Aug. 16, 1906. Temperature: Maximum, 93; minimum, 71; weather, cloudy; moisture, none; condition of pavement, dry.		Saturday, Sept. 1, 1906. Temperature: Maximum, 71; minimum, 57; weather, cloudy; moisture, 0.29; condition of pavement, wet.		Thursday, Sept. 20, 1906. Temperature: Maximum, 71; minimum, 61; weather, cloudy; moisture, 0.70; condition of pavement, wet.	
	Number.	Tons.	Number.	Tons.	Number.	Tons.	Number.	Tons.
Loaded:								
1-horse rubber tire	19	29.5	17	25.5	13	19.5	7	10.5
1-horse steel tire	266	399	286	429.	402	603	287	430.5
2-horse rubber tire	50	225	25	112.5	19	85.5	14	63
2-horse steel tire	528	2,376	572	2,574	592	2,664	548	2,466
4-horse steel tire	34	272	28	224	7	56	13	104
Light:								
1-horse rubber tire	294	294	221	221	248	248	209	209
1-horse steel tire	765	765	1,160	1,160	1,051	1,051	1,144	1,144
2-horse rubber tire	57	142.5	110	275	115	287.5	105	262.5
2-horse steel tire	334	835	461	1,152.5	407	1,017.5	467	1,167.5
4-horse steel tire	18	72	32	128	4	16	16	64
Horses	2	1.2	4	2.4	2	1.2	6	3.6
Bicycles	1,353	135.3	1,064	106.4	1,052	105.2	929	92.9
Automobiles	218	327	335	502.5	237	355.5	152	228
Total	3,938	5,873.5	4,315	6,912.8	4,149	6,509.9	3,897	6,245.5
Average tons per foot of roadway		117.47		138.26		130.16		124.91
Estimating 90 per cent of travel on middle 25 feet of roadway, average tons per foot		211.45		249.22		234.28		224.84
Teams trotting	1,618		2,038		1,980		1,912	
Teams walking	747		874		878		898	

Classification of travel.	Monday, Oct. 1, 1906. Temperature: Maximum, 70; minimum, 45; weather, clear; moisture, none; condition of pavement, dry.		Tuesday, Oct. 16, 1906. Temperature: Maximum, 74; minimum, 51; weather, clear; moisture, none; condition of pavement, dry.		Thursday, Nov. 1, 1906. Temperature: Maximum, 49; minimum, 32; weather, partly cloudy; moisture, none; condition of pavement, dry.		Tuesday, Nov. 16, 1906. Temperature: Maximum, 38; minimum, 32; weather, cloudy; moisture, 0.66; condition of pavement, wet.	
	Number.	Tons.	Number.	Tons.	Number.	Tons.	Number.	Tons.
Loaded:								
1-horse rubber tire	11	16.5	29	43.5	21	31.5	6	9
1-horse steel tire	485	727.5	570	855	276	414	353	529.5
2-horse rubber tire	10	45	81	364.5	63	283.5	38	171
2-horse steel tire	615	2,767.5	657	2,956.5	677	3,046.5	472	2,124
4-horse steel tire	27	216	40	320	31	248	11	88
Light:								
1-horse rubber tire	262	262	340	340	264	264	109	109
1-horse steel tire	966	966	821	821	1,165	1,165	656	656
2-horse rubber tire	73	182.5	88	220	192	480	90	225
2-horse steel tire	337	842.5	345	862.5	480	1,200	357	892.5
4-horse steel tire	27	108	36	144	21	84	2	8
Horses	5	3	2	1.2			5	3
Bicycles	1,234	123.4	1,153	115.3	749	74.9	31	3.1
Automobiles	248	372	247	370.5	172	258	61	91.5
Total	4,300	6,631.9	4,409	7,414	4,111	7,549.4	2,191	4,909.6
Average tons per foot of roadway		132.64		148.28		150.99		98.19
Estimating 90 per cent of travel on middle 25 feet of roadway, average tons per foot		238.75		266.90		271.77		176.75
Teams trotting	1,856		1,940		2,263		1,353	
Teams walking	957		1,067		927		741	

TABLE 6.—*Records of travel on Nicollet Avenue between Washington Avenue and Second Street during year 1906*—Continued.

Classification of travel.	Saturday, Dec. 1, 1906. Temperature: Maximum, 28; minimum, 6; weather, clear; moisture, none; condition of pavement, dry.		Wednesday, Dec. 19, 1906. Temperature: Maximum, 34; minimum, 21; weather, cloudy; moisture, trace; condition of pavement, dry.		Total average.	
	Number.	Tons.	Number.	Tons.	Number.	Tons.
Loaded:						
1 horse rubber tire					12.3	18.5
1-horse steel tire	236	354	362	543	352.3	528.4
2-horse rubber tire	1	4.5	2	9	30.3	136.4
2-horse steel tire	506	2,277	549	2,470.5	571.6	2,572.2
4-horse steel tire	12	96	11	88	21.4	171.2
Light:						
1-horse rubber tire	155	155	159	159	226.1	226.1
1-horse steel tire	1,015	1,015	897	897	964	964
2-horse rubber tire	119	297.5	88	220	103.7	259.3
2-horse steel tire	574	1,435	467	1,167.5	422.9	1,057.2
4-horse steel tire	8	32	12	48	17.6	70.4
Horses			2	1.2	2.8	1.7
Bicycles	208	20.8	81	8.1	785.4	78.5
Automobiles	76	114	85	127.5	183.1	274.7
Total	2,910	5,800.8	2,715	5,738.8	3,693.5	6,358.6
Average tons per foot of roadway		116.02		114.77		127.17
Estimating 90 per cent of travel on middle 25 feet of roadway, average tons per foot		208.83		206.60		228.94
Teams trotting	1,825		1,683			1,846.68
Teams walking	801		864			875.4

TABLE 7.—*Detailed average travel records on Nicollet Avenue between Washington Avenue and Second Street during 1907.*

Classification of travel.	Averages.				Total average for the year.[1]	
	For the first 3 observations when there was snow.		For the last 16 observations.			
	Number.	Tons.	Number.	Tons.	Number.	Tons.
Loaded:						
1-horse rubber tire	[2] 194.7	292	48.8	73.2	71.8	107.7
1-horse steel tire	[3] 146	219	543.8	815.7	481	721.5
2-horse rubber tire	[3] 327	1,471.5	50	225	93.7	421.8
2-horse steel tire	[3] 139	625.5	637.7	2,869.6	559	2,515.3
4-horse rubber tire	[2] 1.4	10.7			1.4	10.7
4-horse steel tire	[3] 2.4	18.7	29.5	236	25.2	201.7
Light:						
1-horse rubber tire	[2] 505	505	199.4	199.4	247.7	247.7
1-horse steel tire	[3] 117	117	799.9	799.9	692.1	692.1
2-horse rubber tire	[2] 263	657.5	73.1	182.8	103.1	257.8
2-horse steel tire	[3] 74	185	421.2	1,053	366.4	915.9
4-horse rubber tire	[2] 1	4			1	4
4-horse steel tire	[3] 2.4	9.3	17.7	70.8	15.3	61.1
Horses	6	3.6	9.9	5.9	9.3	5.5
Bicycles	5.7	.6	976.9	97.7	823.6	82.4
Automobiles	15.7	23.5	288.8	433.1	245.7	368.4
Total	1,800.3	4,142.9	4,096.7	7,062.1	3,736.3	6,613.6
Average tons per foot of roadway		82.86		141.24		132.02
Estimating 90 per cent of travel on middle 25 feet of roadway, average tons per foot		149.15		254.24		237.65
Teams trotting	1,538.7		1,775.6		1,738.2	
Teams walking	234.2		1,045.5		917.4	

[1] This column did not appear in the city engineer report for 1907, but was added in order to make the summaries uniform.
[2] Sleds.
[3] Wagons.

TABLE 8.—*Detailed average travel records on Nicollet Avenue between Washington Avenue and Second Street during 1908.*

Classification of travel.	Averages.				Total average for the year.	
	For the first 2 observations when there was snow.		For the last 10 observations.			
	Number.	Tons.	Number.	Tons.	Number.	Tons.
Loaded:						
1-horse rubber tire	[1] 156	234	31	46.5	51.8	77.8
1-horse steel tire	[2] 265	397.5	432.7	649.1	404.7	607.2
2-horse rubber tire	[1] 127.5	573.7	45.2	203.4	58.9	265
2-horse steel tire	[2] 334.5	1,555.3	682.5	3,071.2	624.5	2,818.6
4-horse steel tire	[2] 2	16	28.6	228.8	24.1	193.4
Light:						
1-horse rubber tire	[1] 286	286	248	248	254.3	254.3
1-horse steel tire	[2] 409	409	1,005.4	1,005.4	906	906
2-horse rubber tire	[1] 130	325	125.9	314.8	126.6	316.5
2-horse steel tire	[2] 254	635	521.4	1,303.5	476.9	1,192.1
4-horse rubber tire	.....	.....	.1	.4	.1	.4
4-horse steel tire	[2] 1.5	6	19.2	76.8	16.3	65
Horses	1.5	.9	5.4	3.2	4.8	2.8
Bicycles	19	1.9	919.7	92	769.6	76.9
Automobiles	121.5	182.3	520.7	781.1	454.2	681.3
Total	2,107.5	4,622.6	4,585.8	8,024.2	4,172.8	7,457.3
Average tons per foot of roadway	.....	92.45	.....	160.49	.....	149.15
Estimating 90 per cent of travel on middle 25 feet of roadway, average tons per foot	.....	166.41	.....	288.87	.....	268.46
Teams trotting	1,439	.....	2,134.6	.....	2,018.7	.....
Teams walking	526.5	.....	1,005.4	.....	925.6	.....

[1] Sleds. [2] Wagons.

TABLE 9.—*Detailed average travel records on Nicollet Avenue between Washington Avenue and Second Street during 1909.*

Classification of travel.	Averages.				Total average for the year.	
	For the first 2 observations when there was snow.		For the last 10 observations.			
	Number.	Tons.	Number.	Tons.	Number.	Tons.
Loaded:						
1-horse rubber tire	159.5	239.2	36.5	54.7	57	85.5
1-horse steel tire	111	166.5	541.2	811.3	468.5	703.9
2-horse rubber tire	245	1,102.7	52.7	237.6	84.7	381.8
2-horse steel tire	231.5	1,047.5	633.2	2,848.7	566.3	2,548.5
4-horse steel tire	1.5	12	33	264	27.7	222
Light:						
1-horse rubber tire	502.5	502.5	161.9	161.9	218.7	218.7
1-horse steel tire	295.5	295.5	702.6	702.6	634.7	634.7
2-horse rubber tire	276.5	691.5	58.4	146	94.7	237
2-horse steel tire	246.5	616	412.6	1,031.5	385	962.3
4-horse steel tire	1	4	23.6	94.4	19.8	79.2
Horses	4.5	2.7	7.8	4.7	7.3	4.4
Bicycles	6	.6	737.2	73.7	615.3	61.5
Automobiles	172.5	258.7	647.4	971	568.3	852.3
Total	2,253.5	4,939.8	4,048.1	7,623.2	3,748	7,175.9
Average tons per foot of roadway	.....	98.79	.....	152.46	.....	143.52
Estimating 90 per cent of travel on middle 25 feet of roadway, average tons per foot	.....	177.9	.....	274.9	.....	258.5
Teams trotting	351.3	.....	989.3	.....	882.4	.....
Teams walking	1,719	.....	1,666.5	.....	1,674.7	.....

TABLE 10.—*Detailed average travel records on Nicollet Avenue between Washington Avenue and Second Street during 1910.*

Classification of travel.	Averages.				Total average for the year.	
	For the first 2 observations when there was snow.		For the last 10 observations.			
	Number.	Tons.	Number.	Tons.	Number.	Tons.
Loaded:						
1-horse rubber tire	126	189	20.9	31.3	38.4	57.6
1-horse steel tire	70	105	351.7	527.6	304.8	457.2
2-horse rubber tire	224.5	1,010.25	36	162	67.4	303.3
2-horse steel tire	110	495	669.9	3,014.5	576.6	2,594.7
4-horse rubber tire	.....	.....	.1	.8	.1	.6
4-horse steel tire	.....	.....	39.4	315.2	32.8	262.7
Light:						
1-horse rubber tire	375	375	183.4	183.4	215.3	215.3
1-horse steel tire	124	124	865.5	865.5	742	742
2-horse rubber tire	246.5	616.25	113.3	283.3	135.5	338.8
2-horse steel tire	129.5	323.75	565.4	1,413.5	492.7	1,231.7
4-horse rubber tire	.5	2	.2	.8	.2	1
4-horse steel tire	1.5	6	31.9	127.6	26.8	107.2
Horses	4	2.4	4.7	2.8	4.6	2.7
Bicycles	1	.1	803.4	80.3	669.7	66.9
Automobiles	201	301.5	1,023.7	1,535.6	886.6	1,329.9
Total	1,613.5	3,550.25	4,709.5	8,544.21	4,193.5	7,711.6
Average tons per foot of roadway	.....	71	.....	170.88	.....	154.23
Estimating 90 per cent of travel on middle 25 feet of roadway, average tons per foot	.....	127.8	.....	307.20	.....	278
Teams trotting	1,220	.....	1,842	.....	1,739	.....
Teams walking	187	.....	1,035	.....	894	.....

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U. S. DEPARTMENT OF AGRICULTURE,

FOREST SERVICE—Circular 195.

(Supersedes Circular 100.)

HENRY S. GRAVES, Forester.

FOREST PLANTING IN THE NORTHEASTERN AND LAKE STATES.

18909°—Cir. 195—12 WASHINGTON : GOVERNMENT PRINTING OFFICE : 1912

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FOREST PLANTING IN THE NORTHEASTERN AND LAKE STATES.

THE REGION.

The suggestions contained in this circular are applicable to the New England States, New York, northern New Jersey, all of Pennsylvania, western Maryland, the high plateau region of West Virginia and the higher portions of the Appalachians south of it, and to Michigan, Wisconsin, and eastern Minnesota.

ADVISABILITY OF FOREST PLANTING.

While the need for tree planting has not been felt in New England and the Lake States as keenly as in the treeless West, large areas of land within this region are fit only for forest growth. From an economic standpoint it is important that these lands should be put into a state of productiveness. Extensive forest planting has thus far been somewhat discouraged by present methods of taxation and in part of the region by the difficulty in securing adequate protection from fire. The true value of forest land and its rightful place among the permanent resources of the State are, however, becoming recognized, and an enlightened public sentiment is rapidly making this form of investment safe and profitable.

CUT-OVER LANDS.

Throughout the Northeastern States and the Lake region are large areas of forest land which have been lumbered and afterwards swept by successive fires. Repeated burnings have largely destroyed young trees of valuable species, and these have been succeeded by stands of aspen, wild red cherry, scrub oak, red maple, and shrubs, all of low value. Such land presents to the tree planter a difficult problem, because not only will the expense of the initial planting be rather high, owing to the dense growth already on the ground, but the young trees are likely to be overcome in competition with it. Added to these difficulties is the great danger from fire. This is especially true in the Lake States and Pennsylvania. The land, however, in its present condition, has a very low producing value, and where adequate fire protection can be provided forest planting is strongly recommended.

On recently cut-over areas which have not been burned and on which a few trees are left that will furnish seed, planting is seldom necessary, for the more valuable species will usually come in without artificial aid. Cut-over lands which have recently been burned, so that the growth of worthless species is checked, offer exceptionally good opportunities for planting. Lands on which sprout or seedling growth is scarce or poorly distributed may be reforested by planting the bare areas.

WORN-OUT AGRICULTURAL LAND.

There is a large amount of land, particularly in New England and Michigan, which was cleared for farming, but which afterwards deteriorated in value, principally through loss of fertility. Throughout Massachusetts, Connecticut, and New Hampshire, many of these abandoned farms and old pastures grew up to white pine. This crop is rapidly being removed, and because no seed trees are being left little natural reproduction is taking place. Such lands, because of their nearness to market and their freedom from brush cover, offer exceptionally fine opportunities for forest planting.

SAND DUNES AND BARRENS.

There are large areas of barren sand plains, notably in Connecticut, Rhode Island, New Hampshire, Massachusetts, New Jersey, and Michigan, which can not be tilled and which are a source of expense to their owners. These sandy lands are suited to the requirements of several hardy conifers, and, in many instances, will even support a good growth of white pine. As in the case of sand dunes, the problem is not one of purely commercial planting, but of preventing drifting sand from encroaching on valuable property.

WATERSHED PROTECTION.

The policy of artificially establishing a forest cover on denuded watersheds for the protection of municipal water supplies is being followed by many of the larger towns and cities, and is deserving of more general adoption. A forest cover upon a watershed not only protects the purity of the water, but effectively regulates its run-off, materially reduces the amount of erosion, and prevents to a large extent the silting up of reservoirs. Streams upon bare watersheds, on the other hand, drain off the rainfall rapidly, in muddy torrents, culminating in the common spring flood, to be followed, in time of drought, by extreme scarcity of flow. Wherever natural reproduction can not be depended upon to cover the pastures and bare lands of reservoir watersheds with forest growth, tree planting should be practiced. While the immediate object of this forest planting will be

protective, timber crops will eventually be produced which will yield good profits.

THE WOODLOT.

Nearly every farm has at least a few acres which are of little value for growing agricultural crops. This land should be set aside for a woodlot and devoted to the production of fuel, fence posts, and timber for farm uses. Large open spaces in existing woodlots can be restocked with valuable species, thus making every part of the land productive. This is best done on lands from which the trees have recently been cut. In addition to producing wood material, the farm woodlot may, in some instances, be made to serve as a shelter belt to protect the buildings or orchards from wind or snow.

METHODS OF PLANTING.

The best method of establishing a forest plantation is by the use of nursery stock. It is usually advisable to purchase plant material from a commercial nursery. In extensive operations, however, it may prove more profitable to produce the planting stock in a home nursery. Such a nursery, however, will demand the careful supervision of one experienced in growing young trees.

Forest planting must be done by simple and cheap methods. Preparation of the planting site by plowing and harrowing is not essential, but is best if the land has been previously utilized for crops. Such preparation and cultivation improve the early growth of the trees, but add to the initial cost of the plantation.

Trees should be planted with the least possible exposure of the roots. The rootlets of the plant will dry out if exposed to the air for even a short time. This is especially true of conifers. Some of the broadleaf species may, with proper attention, live even after the roots have dried out, but conifers are far less likely to survive.

When the seedlings are received, they should be unpacked at once and their roots dipped into a pail containing thin mud. Until time for planting in the field the trees should be "heeled in" according to the following method: Dig a trench deep enough to bury the roots and part of the stems. The trench should run east and west, with its south bank at a slope of about 30° to the surface of the ground and with the dirt thrown out on the south side. A layer of trees should be placed in the trench on its sloping side, the tops toward the south. The roots and stems should be covered with fresh earth dug from the north side of the trench, on which a second layer of trees is put and covered in the same way. The widening of the trench by digging from the north side is repeated and layers of trees are put in until all have been heeled in. (See fig. 1.)

In the case of conifers care should be taken not to bury the foliage, and either to choose a shady place for the young trees or to construct a shade over them with brush or laths.

The best time to plant trees is in the early spring, before the growth begins. In general, planting should be done as soon as possible after the frost is out of the ground. The trees should be carried to the planting sites roots downward in a pail containing several inches of water. They should be set in holes made with a dibble or dug with a mattock or spade. The width and depth of the holes will depend on the character and size of the plant's root system. The trees usually should be set in the ground slightly deeper than they were in the nursery. In all tree planting it is of the greatest importance to press the earth firmly about the roots, so that all air spaces are filled. The soil should not, however, be packed so hard as to be impervious to water, nor should the earth be raised in a mound about the stem.

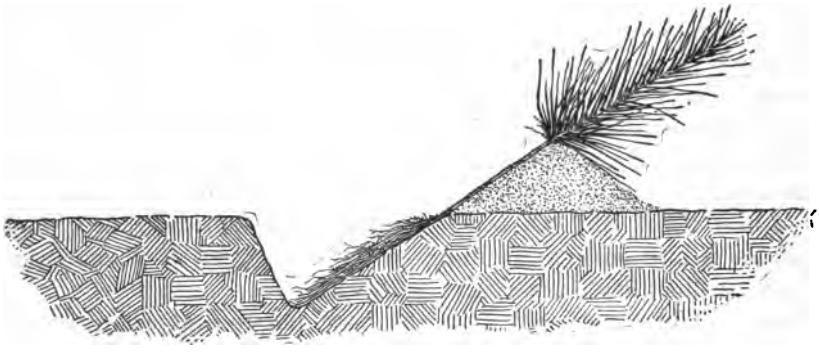

FIG. 1.—Heeling in young trees.

Information regarding general nursery practice and planting may be obtained from publications of the Forest Service, which will be forwarded upon request addressed to the Forester.

PROTECTION.

Protection to forest plantations must be assured before success is possible. Fire must be guarded against; otherwise the investment is likely to be a total loss. Local conditions must be such that the danger from fire is reduced to a minimum. Cattle must be rigidly excluded from the area planted, since grazing is decidedly injurious.

Plantations should be carefully watched to detect the presence of injurious insects. Insect damage should be reported promptly, and specimens of insects which attack the seedlings should be mailed to the Bureau of Entomology of the United States Department of Agriculture, which will identify them and suggest measures for their control.

SPECIES FOR PLANTING.

In general, conifers are best adapted for planting in the region, on account of their more rapid growth. Conifers produce a variety of material which is in great demand. They also are far superior to deciduous trees for protective planting. To supply special demands in certain localities, it is sometimes desirable to grow crops of a particular species. Thus, willows may be planted for basket material or fine grades of charcoal; basswood and cottonwood may be grown for wood pulp, and black locust for fence posts.

Species which are well suited for planting in the region are white pine, red (Norway) pine, Scotch pine, pitch pine, jack pine, Norway spruce, European larch, ash, chestnut, sugar maple, and red oak. The Forest Service will send, upon request, lists of dealers in these and other species.

WHITE PINE (*Pinus strobus*).

White pine is suitable for planting on nonagricultural lands throughout the region. Much of the abandoned farm land in the New England States may profitably be planted with white pine, and the tree is well adapted to burned and cut over forest lands and to watersheds.

White pine grows best on a fresh, light, deep, and sandy soil with a porous subsoil. It will succeed, however, on a variety of soils, from fresh, medium-heavy clay and loam to dry sands. It will endure windy and cold exposures, but should not be planted near the seacoast, since it will not endure strong sea breezes.

Plantations of white pine are best established by the use of 3-year-old transplants. The trees should be planted 6 feet apart each way. They may be planted either pure or in mixture with shade-enduring hardwoods or conifers. It is essential, however, that the associated species should be of slower growth, since otherwise they will overtop and kill the pine. There are also certain light-demanding species of rapid growth which may be mixed with white pine. These, while they may overtop the pine, cast so light a shade that its development will not be retarded. The more important species for planting in mixture with white pine are chestnut, European larch, Norway spruce, red oak, and sugar maple. Ordinarily white pine and the associated species should be planted alternately, so that the white pine will make up half the stand. In mixture with European larch, however, white pine should constitute at least two-thirds of the stand.

Commercial plantations of white pine should be cut when from 40 to 70 years old. At this time the trees will be from 50 to 80 feet high and from 12 to 18 inches in diameter. The larger trees will

furnish saw timber, while the bulk of the plantation will find ready sale as box boards, pail staves, match blocks, woodenware, and straight cooperage. Where there is a demand for small material, the stand may be profitably thinned at the age of 20 to 30 years.

Because of its thin bark young white pine is very susceptible to injury by fire. Between the fifth and twentieth years, however, the greatest cause of injury to the white pine is the weevil, which, in the grub stage, mines in the terminal shoot and causes a crooked stem. Repeated attacks make the tree unmerchantable.

RED PINE (*Pinus resinosa*).

Red pine may be planted on situations similar to those recommended for white pine. In form and rapidity of growth it is very similar to white pine, and because of its freedom from insect injury may sometimes profitably be substituted for it. The wood is valuable for all kinds of house lumber, and when chemically treated makes good posts and ties. It is somewhat stronger than white pine, and in the coal regions will be valuable for mine props. In most of its qualities it is somewhat similar to the shortleaf pine of the South.

Two-year-old seedlings or three-year-old transplants should be used and the trees planted 6 feet apart each way. Red pine is well adapted to pure plantations, but it may be mixed with European larch, chestnut, red oak, and sugar maple. The tree is very light demanding, and it is essential that associated species should not suppress it. To prevent this the other species should, in general, be of slower growth. European larch, however, though it grows faster than red pine, is a very desirable tree in mixture, since its crown casts little shade. When planted with red pine it should never exceed a proportion of one to three in the plantation. In all other mixtures red pine and the associated species should be planted alternately, so that red pine will make up half the stand.

SCOTCH PINE (*Pinus sylvestris*).

Scotch pine is native to Europe, though it has been planted to some extent throughout the northern United States. It resembles red pine, and, although inferior to our white pine in many respects, will often prove an excellent substitute. It is indifferent to soil requirements and is well adapted to planting on sterile sands and in exposed situations.

In this country, except for fuel, no practical use has ever been made of Scotch pine. Abroad it is one of the most important woods of commerce and furnishes the famous "red" and "yellow" deals of the British timber trade. Although the wood is not durable in contact with the soil, large quantities are used for crossties and mine props,

its value for such uses often being increased by impregnation with wood preservatives. Small-sized material is widely used for staves, heading, box boards, etc., but the largest use of the timber is for general construction purposes.

In planting, the trees may be spaced 5 or 6 feet apart each way. The exact distance will depend upon the site. On somewhat unfavorable situations the closer spacing is advisable. To secure proper form development the trees require considerable crowding while young; hence wide planting should never be practiced.

Although for favorable situations younger plant material may be suitable, the use of 3-year-old transplants is advised. Scotch pine may be grown either pure or mixed, but should never be associated with heavy-foliaged trees of equal or more rapid growth. Suitable associates are European larch, Norway spruce, white pine, and red pine.

JACK PINE (*Pinus divaricata*) AND PITCH PINE (*Pinus rigida*).

Jack pine and pitch pine are both very hardy trees, suited to sterile, sandy soils. If ground water is not too far below the surface, they can be planted with good prospects of success where few other trees will grow. Both species will withstand considerable drought, and are rarely injured by frost. Planting of these species should be limited strictly to sterile situations, such as sand dunes and sand barrens, where more valuable trees will not thrive—jack pine in the northern and western parts of the region to which this circular is applicable, and pitch pine in the southern and eastern portions.

Three-year-old transplants should be used wherever the planting is on poor sites, and the trees spaced not more than 6 feet apart each way or preferably only 4 feet. Both species are well adapted for pure planting, which is the method usually advisable.

Since these species will be confined to poor soils, the returns will be comparatively small, yet areas otherwise practically worthless may be utilized for the production of cordwood or rough lumber. It should be possible to grow at least one-third of a cord per acre annually on such sites on a 40-year rotation.

EUROPEAN LARCH (*Larix europæa*).

The European larch is not indigenous to the United States. It is a deciduous conifer similar in form and size to our native tamarack. Small plantations of larch have been made throughout the Northern States, and in height growth is equalled by but few other conifers suitable for planting in the region.

Larch requires favorable soil conditions. The soil should be deep, light, moderately fertile and fresh, and well drained both in the

upper layer and subsoil. When the land is wet the tree may start vigorously, but it will soon become spongy at the base and rot. It will grow on comparatively poor soil.

The wood of larch is heavy, hard, strong, flexible, and very durable in contact with the ground. When grown on good soil it is yellowish white, but in cold, elevated situations it is reddish brown and much harder. Because of its strength and durability it is very valuable for posts, poles, crossties, etc., and is largely used in shipbuilding.

Plantations may be established by the use of 2-year-old seedlings. The planting should be done very early in the spring, since the buds start early. The trees should be spaced 6 feet apart each way.

Mixed plantations are most desirable, since European experience shows that pure plantations of larch do not thrive for any length of time. Chestnut and larch and red pine or white pine and larch are admirable for planting on a large scale. In such mixtures the larch should be in the proportion of 1 to 3 or more.

NORWAY SPRUCE (*Picea excelsa*).

Norway spruce, an introduced species, has been planted over a wide area in the United States. It is more rapid in growth than our native spruce and is well adapted for planting for pulpwood on cut-over lands of the Northeast. It will adapt itself, within certain limits, to situations formerly occupied by our spruce forests, and it is in many respects a superior tree.

In the United States little use has so far been made of Norway spruce. The timber is light, soft, nonresinous, and fairly durable. It works well, splits easily, and seasons without serious warping. Abroad, its largest uses are for construction timber, fuel, and paper pulp. Its utility for the last purpose should lead to extensive commercial planting in this country. The timber may also be used for general construction purposes as a substitute for white pine. It is very suitable for hedges and windbreaks and may be planted as a protection belt about exposed hardwood groves.

Norway spruce does not demand a deep, rich soil. It will grow well in a fresh, shallow, moderately porous soil, whether fertile or not, but will not thrive in extremely dry situations. In common with our native spruces, it is shade-enduring and forms dense stands which protect the soil and maintain forest conditions.

Plantations are best started with 3-year-old trees, one year transplanted. The trees should ordinarily be set 4 to 6 feet apart each way. Norway spruce makes excellent development in pure stands. If planted in mixture with other species, the best associates are white pine, red pine, European larch, and chestnut.

CHESTNUT (*Castanea dentata*).

Of the hardwood trees suitable for planting in this region, chestnut is among the best in regions where it is free from disease. It yields comparatively quick returns in timber valuable for a wide range of uses. Large areas throughout the East, particularly in New England, Pennsylvania, and New York, are well adapted to chestnut. It does not occur naturally in the northern portions of New York or New England, nor in the Lake States, except Southern Michigan, but is abundant throughout the remaining portion of the region. If planted too far north, the shoots fail to become woody before they are nipped by the early frosts. The tree will endure the heat and cold of its natural home, however, and will remain thrifty in sunny, dry situations.

Chestnut timber is in great demand. The wood works easily and is very durable in contact with the soil. It is used in cabinetwork and cooperage and for fence posts, telegraph and telephone poles, ties, and mine timbers. The presence of tannin in the wood increases the demand for small-sized and inferior material, and large quantities are used in the manufacture of tannin extracts.

Chestnut will thrive on a variety of soils, from almost pure sand to coarse gravels and shales. On limestone soils, however, it never makes good growth. In general it prefers the dry, well-drained, rocky land of the glacial drift to the richer, more compact, alluvial soils of the lowlands.

The trees should be planted 6 feet apart each way. If they are to be grown directly from the seed without transplanting, seed spots should be prepared. Two or three nuts should be planted in each and covered about 1 inch deep with fine earth. Only one tree should be allowed to remain in each hill. This method is recommended by many, and where there is no danger from squirrels it will prove satisfactory and less expensive than the use of seedlings. In general, however, the planting of 1-year-old seedlings will be safer and will give better results.

The system of management best suited to chestnut is the pure coppice, with a rotation of from 45 to 60 years, although on good soils fence posts can be grown in 20 years or ties in from 35 to 40 years. Sprouts make more rapid growth than seedling trees and produce timber in many respects superior. Chestnut grows well in mixtures, particularly with white pine, red pine, and European larch, and with the oaks, ashes, and maples.

Within the past 10 years chestnut in Connecticut, southern New York, New Jersey, Pennsylvania, Maryland, and in portions of other eastern States has been attacked by a destructive fungous disease, the chestnut blight. Since no practical means of combating this disease

have yet been found, the establishment of chestnut plantations within the infested area, or within considerable distances around it, is considered inadvisable.

RED OAK (*Quercus rubra*).

Red oak exceeds all other oaks in rapidity of growth. It is recommended for planting throughout the region, with the exception of the extreme northern portion, on soils of medium quality and on those which have become exhausted by cultivation.

Red oak is inferior to white oak in strength and durability, though it is often substituted for it. It is used for cabinet work and interior finish. By far the greatest argument in favor of planting red oak, however, is the possibility of substituting its timber for that of white oak in crossties. White oak is not suitable for commercial planting in this region, since its slow growth makes such planting unprofitable. Although an excellent tie timber, red oak is not durable in contact with ballast. By the use of wood preservatives, however, a red-oak tie can be made more durable than one of untreated white oak.

Red oak is best suited to porous soils—either sandy, loamy, or gravelly-clay. The tree is intolerant of shade, except when very young, and must always be allowed to keep its crown free.

Plantations are best established by the use of 1-year-old seedlings. The trees should be planted 6 feet apart each way. It is often advisable and less expensive to plant the acorns in seed spots in their permanent place in the field. The acorns are bitter and are not likely to be molested by squirrels. Three or four acorns should be placed in each spot and covered with about 1 inch of fine earth.

Red oak may be grown in pure stands, but it is suitable for mixture with white pine, European larch, red pine, and with hardwoods, such as chestnut and sugar maple.

WHITE ASH (*Fraxinus americana*).

White ash, which grows scatteringly throughout this region on the better soils, is one of our most valuable hardwood species. The high quality of its wood, its rapid growth as compared to other species which produce wood of equal value, and the ease of propagation are all features which recommend it for planting. The wood is exceptionally strong, tough, and elastic, takes a high polish, seasons without injury, and is fairly durable in contact with the soil. Its chief uses are for vehicle and car construction, agricultural implements, tools, furniture, and interior woodwork. It has also been used satisfactorily for fence posts. First-class posts can be obtained from plantations on good soils in from 15 to 20 years.

White ash should be planted preferably on rich, moist, permeable soils, and is well adapted to alluvial river bottom lands, even where

subject to periodic overflow. Plantations can best be established with 1-year-old seedlings, which on good soils should be spaced about 6 feet each way. It is advisable before setting the trees to prepare the planting site in the same manner as for farm crops. Ash may be planted either pure or in mixture. Some of the species best adapted for planting with it are sugar maple, black cherry, basswood, elm, white and Scotch pines, and European larch. Thorough and frequent cultivation to keep out weeds and grass should be given the plantation for the first three seasons, or until the ground is well shaded. If the stand is thinned when from 20 to 25 years old, it should be possible on the best sites to cut clean at 45 years, at which time the diameters should run from 9 to 15 inches breast high. The stand can be renewed by sprouts from the stump, but it may be advisable to fill in the open spaces caused by former thinnings with seedling stock.

SUGAR MAPLE (*Acer saccharum*).

Sugar maple is a comparatively slow-growing tree. It may be planted throughout the Northeastern and Lake States, on moderately rich, well-drained soils. It can not maintain itself on poor, dry ground.

The wood of sugar maple is used in large quantities for flooring and interior finish and in the manufacture of woodenware, spindles, and novelties. It has a very high fuel value and produces high-grade charcoal. Sugar maple is also used to a considerable extent in the manufacture of implements and vehicles.

Sugar maple has great worth as a filler in plantations of more valuable rapid-growing trees. Its wide planting range, hardiness, tolerance, and heavy crown make it well suited for this purpose. By planting the more valuable species in mixture with sugar maple the cost of the stand at maturity is reduced, since maple seedlings are cheap and easily obtained. To secure proper form development it is often necessary, in forest planting, to set out a much greater number of plants than can remain on the area when the trees increase in size. It is obvious, therefore, that the temporary portion of the stand should represent as small an outlay as possible, since little returns can be expected from this source.

Sugar maple may be planted in mixture with white pine, red pine, European larch, ash, chestnut, and red oak. Two-year-old seedlings are suitable for planting, and may be obtained at a cost much less than that of species with which they will be associated.

Approved:

JAMES WILSON,
Secretary of Agriculture.

WASHINGTON, D. C., *October 24, 1911.*

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U. S. DEPARTMENT OF AGRICULTURE,

FOREST SERVICE—Circular 196.

HENRY S. GRAVES, Forester.

THE INFLUENCE OF AGE AND CONDITION OF THE TREE UPON SEED PRODUCTION IN WESTERN YELLOW PINE.

BY

G. A. PEARSON,

In Charge, Fort Valley Experiment Station.

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1912

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THE INFLUENCE OF AGE AND CONDITION OF THE TREE UPON SEED PRODUCTION IN WESTERN YELLOW PINE.

TESTS ON WESTERN YELLOW PINE SEED.

The influence of the character of the mother plant upon the quality and quantity of seed produced and upon the character of the offspring is a factor which is well recognized in plant breeding. In forestry this factor should be considered not only in collecting seed for artificial propagation, but also in the selection of trees to provide for the natural regeneration of cut-over areas. In selecting seed trees the forester must ask himself: "Which trees will produce the best quality and the greatest quantity of seed?" and finally, "Which will produce the most desirable seedlings?" Secondary, though very important, considerations which should govern the forester in his selection of trees to provide for the future stand after cutting are wind firmness and merchantable deterioration or appreciation.

This circular deals primarily with the conditions affecting the germinative quality of the seed. The influence upon the quantity of seed, though of great importance, will be treated only as a secondary topic, because the data on this phase of the subject are incomplete.

The species studied was western yellow pine (*Pinus ponderosa*). The locality was near Maine, Ariz., on the Tusayan National Forest, elevation about 7,200 feet. In November, 1909, 100 samples, each consisting of from about one-tenth to 1 bushel of cones, according to the amount available, were collected from 100 trees representing different ages, sizes, and conditions of soundness and general health. The cones were collected in connection with a logging operation, which made it possible to determine accurately the age and soundness of the tree. In the case of young trees which were not felled the age and soundness had to be estimated; but since the number of such trees was small and nearly all of them were thrifty, the errors in these estimates will not be great enough materially to affect the results. In each case the sample was made up of cones from all parts of the crown. Careful data were taken on each sample, according to the outline on page 4.[1]

[1] The seed samples and accompanying data were gathered by Forest Assistant Harold H. Greenamyre.

Tree No.	Yield of cones (bushels)
Height (feet)	Condition of cones
Diameter breasthigh (inches)	Number of cones in sample
Age (years)	Dry weight sample (pounds)
Clear length	Weight seed (ounces)
Condition of bole	Site:
Condition of crown	Exposure and slope
Fire scar?	Soil
Spike top?	Ground cover
Other peculiarities	Stand

TABLE 1.—*Comparative germination of seed of western yellow pine—Coconino Experiment Station.*

Tree class.	Duration of test (days). Average germination (per cent). 15	20	25	30	40	50	Basis.	Average yield of cones per tree.	Basis.	Average amount of seed per pound of dry cones.	Basis.	Average number of seed per pound.	Basis.
							Trees.	*Bush.*	*Trees.*	*Ounces.*	*Trees.*		*Trees.*
Yellow pine	42	58	61	64	67	68	60	1.8	55	1.3	47	12,065	62
Blackjack	52	69	72	74	75	76	38	1.0	8	1.7	36	12,624	38
Healthy yellow pine	41	55	57	61	63	64	28	1.8	27	1.2	20	11,362	28
Healthy blackjack	53	71	74	76	77	78	34	1.0	8	1.5	13	12,305	34
Unhealthy yellow pine	43	58	65	69	70	71	34	1.7	30	1.4	27	12,644	34
Unhealthy blackjack	44	55	57	59	60	61	4			1.9	2	15,352	4
Open stand[1]	46	62	65	68	70	70	73	1.8	51	1.4	59	12,223	73
Medium stand[1]	41	57	61	65	68	69	18	1.1	13	1.5	16	12,498	18
Dense stand[1]	56	77	78	79	79	79	9	.7	4	1.8	8	12,294	9
By decades:[1]													
140	63	78	80	82	83	84	4	1.2	3	1.5	3		
150	68	84	86	87	87	87	2	1.1	2	1.0	1		
160	55	68	70	71	73	73	7	.8	6	1.5	5		
170	53	68	70	72	74	74	6	1.5	6	1.3	6		
180	36	50	54	58	61	62	11	1.7	10	1.4	7		
190	48	63	69	75	77	77	4	1.7	4	1.2	3		
200	35	74	81	82	82	82	1	4.0	1				
210	33	55	58	61	64	66	8	2.1	8	1.3	5		
220	29	42	45	47	49	50	5	1.0	5	1.2	5		
230	56	77	78	82	83	84	2	1.5	1	1.0	1		
240	48	56	61	66	72	74	2	2.3	2	.9	2		
250	54	86	86	88	88	88	1	1.5	1	2.0	1		
260													
270													
280	20	24	26	33	38	39	2	2.1	2	1.2	2		
290	43	52	57	60	61	61	2	.6	2	1.5	2		
300													
310	36	53	57	62	63	63	1	.3	1				
320	3	7	8	14	22	36	1	2.0	1	1.3	1		
330	38	79	80	81	83	83	1	2.0	1	.9	1		
340	26	50	55	62	70	71	3	1.3	2	1.4	2		
350	70	80	82	83	83	83	2	3.3	2	2.0	1		
360													
370													
380	12	15	16	18	24	27	1	2.5	1	1.2	1		
390	61	70	72	74	75	75	2	3.0	2	1.2	2		
400	43	76	77	78	78	78	1	2.0	1	.9	1		
Below 140 (diameter breast-high 14 inches and below)[2]	52	71	73	77	78	81	20					13,256	21
140–250[1]	45	61	65	69	70	71	[3]64	1.6	49	1.3	39	11,652	63
260–400[1]	37	52	54	58	62	63	16	2.0	15	1.3	13	13,447	16

[1] All trees.
[2] Blackjack, not cut. Age estimated.
[3] Includes 10 "blackjack" 15–22 inches diameter breast-high and 1 "yellow pine" 17 inches diameter breast-high whose exact age was not determined.

Table 1 gives a comparison of the different classes of trees with reference to germination and yield.

The cones were air dried. Each sample was placed in a 2-bushel sack immediately after collecting and kept there through the entire process of drying. The amount placed in each sack was in no case more than 1 bushel, though by the time the cones were fully opened the volume had about doubled. The drying process, which involved daily turning of the sacks, required about six weeks. No rain or snow fell in the meantime. The seeds were extracted by first shaking the cones violently in an iron tub and then striking each cone separately against the side of the tub. They were cleaned by rubbing between the hands, and later allowing the wings to blow out by pouring the mass slowly from one vessel to another in a light breeze, care being exercised to prevent the light, hollow seed shells from blowing out, because obviously these should be considered in the germination tests.

The germination tests [1] were made at Washington by planting 200 seeds from each sample in a sand flat and subjecting them to a hot-house temperature of 60° F. The duration of the test was 52 days, during which period counts were made every two or three days.

The terms "blackjack" and "yellow pine" will be used in this circular to distinguish two forms of the species *Pinus ponderosa*. "Blackjack" is the local name applied to young, vigorous trees characterized by a dark, almost black bark. "Yellow pine" is the local name applied to the older trees characterized by a yellowish or reddish brown bark. Lumbermen generally regard the two forms as distinct species, but the only difference is that due to age.

From Table 1 the following deductions may be made:

GERMINATION.

Seed from young trees shows a higher germination than seed from old, mature, or overmature trees. The 38 blackjacks used in this test give a germination of 76 per cent, against 68 per cent for the 60 yellow pines. A comparison of 20 trees near Cliffs on this Forest in 1908 gave a germination of 68 per cent for yellow pine, against 80 per cent for blackjack. Classifying both blackjack and yellow pine according to age, by decades, the germination per cent is found to fall with the increase in years. This decline is, however, by no means regular. For instance, 5 trees 220 years old show an average germination of only 50 per cent, while 2 trees 390 years old show an average of 75 per cent. Dividing all trees, both yellow pine and blackjack, into three age classes, namely, below 140 years (8 to 14 inches diameter breast-high), 140 to 250 years, and 260 to 400 years, the average germination per cents are found to be 81, 71, and 63, respectively.

[1] Conducted by Mr. N. H. Grubb, Office of Silvics.

Certain injuries decrease while others increase seed quality. A comparison of healthy and unhealthy trees shows the following germination per cents: Healthy yellow pine, 64; unhealthy yellow pine, 71; healthy blackjack, 78; unhealthy blackjack, 61. In classifying the trees with respect to health, those affected by heart rot, insects, mistletoe, dying top, fire scars, and suppression are classed as "unhealthy," while those showing no indications of disease or injury are classed as "healthy." These terms mean but little, however, unless we inquire into the actual condition of the tree. Grouping the 34 trees classed as unhealthy according to the nature of the injury, the following interesting comparison is derived:

TABLE 2.—*Comparative quality of seed from healthy and unhealthy trees.*

	Healthy.		Unhealthy.				
	Yellow pine.	Black-jack.	Heart rot, yellow pine.	Spike top, yellow pine.	Fire scar, yellow pine.	Bark beetle, yellow pine.	Mistletoe, blackjack.
Germination.....per cent..	64	78	67	79	79	37	51
Basis.....trees..	28	34	10	7	15	3	3

Yellow pine affected by heart rot shows a germination 3 per cent higher than that of sound, healthy yellow pine. This difference, based upon only 10 trees, is hardly sufficient to establish the conclusion that heart rot increases germinative quality, but at the same time tends to show that at least the seed of such trees is not inferior to that of sound trees. The smallness of the effect is probably due to the fact that the rot works upon the heartwood exclusively and does not directly attack the vegetative life of the tree. If the rot should become sufficiently advanced to reduce materially the vitality of the tree, it is probable that the quality of the seed would be impaired and the quantity diminished. On the other hand, the fungus in its earlier stages may act as a stimulus, as in the case of "spike top" and fire scars, considered in the paragraphs following.

Spike tops show a germination 15 per cent higher than that of the healthy yellow pine. "Spike top" is the common term applied to trees with dead leaders, generally caused by some mechanical injury, most frequently lightning. The wound is usually followed by a fungous attack. The leader dies back from year to year, and as the upper branches drop away a straight shaft is left projecting above the living portion of the crown. The injuries causing spike top evidently act as a stimulus upon seed production. This peculiarity—apparently nature's provision for the perpetuation of the species—although not fully understood, is a matter of common observation.

It is in accordance with the same natural law which governs sprout growth after a basal burn, and the production of adventitious shoots after an injury on the stems or branches of certain broadleaf trees.

Yellow pine marked by fire scars shows a germination 15 per cent above that of healthy yellow pine. Fire scars are confined almost entirely to the base of the tree. They begin as a small burn in the bark and cambium, but increase in size and depth with recurring fires, until finally they sometimes extend 5 feet or more up, and one-half or two-thirds through the stem. Trees thus affected generally bear no marked signs of reduced vitality except in advanced stages, although possibly measurements might show a diminution in growth. The direct effects of the burn are a reduction of the water supply of the crown of the tree because of the destruction of more or less of the water-transporting elements, and at the same time a reduction of the food supply of the roots through the destruction of some of the elements bringing elaborated food material from the crown to the roots. It is evident that the food supply of the roots will suffer more than the water supply of the crown, because the elements bringing down the food, being nearer the surface, are more readily destroyed by the fire. The eventual result will be a reduction of the food supply of the entire tree, due to a reduction of the amount of water which the tree is able to absorb. In spite of this fact, burns appear to stimulate seed production, as does the injury causing spike top.

Mistletoe-infected blackjack shows a germination 17 per cent below that of unaffected blackjack. Although mistletoe stimulates growth in the immediate region of the parasite, causing the abnormal development of certain branches, the excess of carbohydrates produced by the additional foliage of the mistletoe-stimulated branches is used by the parasite itself, so that the final result is a drain upon the tree. It seems highly improbable that mistletoe would ever act as a stimulus upon seed production, because its action is insidious, slowly sapping the vitality of the tree instead of causing injuries in the nature of a shock, as is the case with burns or other mechanical injuries.

The effect of suppression is not clearly demonstrated. Of the two yellow pine included in our data, one has a germination per cent of 92 and the other only 14.5, the average of the two being 53, or 11 per cent below that of normal yellow pine. The only blackjack tested shows a germination of 90.5 per cent, or 12.5 above that of the average healthy blackjack. On account of the great variation between the individual trees cited above, it is impossible to predict the result of averaging a large number of trees. One would naturally expect to find an inferior quality of seed on a suppressed tree, but this would vary with the degree and period of suppression. It will also be counterbalanced to a certain extent by those factors which

tend to better the quality of seed in dense stands, such as more favorable conditions for pollination and the moderating effect of close crown cover, described in the following paragraph:

The highest quality of seed is produced in dense stands. The germination for open, medium, and dense stands is 70 per cent, 69 per cent, and 79 per cent, respectively. The difference between the open and medium stands is too small to establish any conclusion one way or the other; but the difference in favor of the dense stand is very pronounced. At first thought one might expect to find the highest quality of seed in open stands where light conditions are most favorable. There are, however, a number of factors which tend to explain why the contrary is true. First, it is obvious that the denser stands afford the best conditions for pollination; secondly, the moderating effect of a close crown cover upon temperature and evaporation would favor seed development, especially in the early stages. Many young cones die during the winter and spring, probably as the result of the unseasonable freezes and the drying winds which are very prevalent. Flowers suffer in the same way. Instrumental observations at the Fort Valley station show that the minimum temperatures under a fairly close canopy are commonly from 3° to 17° higher, and the wind movement and evaporation from 50 to 100 per cent less than in the open.

That the age and condition of the tree apparently have no material effect upon the rate of germination is evinced by the fact that the ratio between the germination per cents of different tree classes remains practically constant throughout the period of the test.

YIELD.

No accurate data with regard to the absolute yield in seed are available, but a rough measure of this yield is expressed by the production of cones given in the preceding table. It should be remembered that, in comparing yields with a view to determining the influence of the character of the tree, it is necessary to consider, in addition to the condition of soundness and general health, also the crown development of each tree, a feature which is determined largely by the density of the stand. Moreover, it is to be taken for granted that, other things being equal, the yield will increase with age until a certain age limit is reached. An exact study of the factors influencing both germination and yield is much more complicated than one in which germination alone is considered. Since this study was undertaken with the primary object of determining the conditions affecting germination, the data on yield are incomplete; nevertheless it is worth while to make a few comparisons based upon the data available, making due allowance for the evident inaccuracies in the results.

A comparison of yellow pine and blackjack shows an average yield of 1.8 bushels of cones per tree for the former and 1 bushel for the latter. This difference is attributable mainly to a difference in the size of the trees, the yellow pines on account of their greater age being on the average much larger than the blackjacks. A comparison of the classes with respect to the amount of seed produced by a pound of dry cones gives 1.3 ounces for the yellow pine against 1.7 ounces for the blackjack. It therefore appears that, although the younger trees yield less cones, when the amount of seed produced by a given quantity of cones and the vitality of the seed are considered, these trees are better seed producers for their size than the older trees. In comparing the two age groups from 140 to 250 years and from 260 to 400 years we find, as in the case of the blackjack and yellow pine, a considerably greater yield of cones for the older trees. The amount of seed produced by a pound of cones is, however, the same for both groups. The difference of cone production is much less pronounced between these two age groups than between the blackjack and yellow pine, because many of the trees included in the lower-age class have passed beyond the blackjack stage. Practically no data are available on trees below 140 years, since the trees were not felled, and only a small number of cones were picked from each tree.

A comparison of the healthy and unhealthy yellow pine shows only a slight difference in cone production. There appears a pronounced difference between the healthy and unhealthy blackjack, but, since we have accurate data for only two unhealthy blackjacks, this comparison is not conclusive. Furthermore, as in the case of germination; a comparison of healthy and unhealthy trees is of little significance unless we consider the nature of the injury in the unhealthy trees.

A comparison of the trees classed as unhealthy, considering the nature of the disease or injury, is shown in Table 3.

TABLE 3.—*Comparative yield of cones from healthy and unhealthy trees.*

	Healthy.		Unhealthy.				
	Yellow pine.	Blackjack.	Spike top, yellow pine.	Fire scar, yellow pine.	Heart rot, yellow pine.	Bark beetle, yellow pine.	Suppressed, 4 yellow pine, 1 blackjack.
Yield of cones per tree. bushels..	1.8	1	0.9	2.1	2.1	1.1	0.4
Basis.....trees..	27	14	6	15	10	3	4

Although the yellow pines affected by heart rot show a yield of 0.3 bushel more than the healthy trees of this class, the difference is probably due mainly to the fact that the trees affected by heart rot

are usually old and consequently of large size. The average diameter of the healthy yellow pine in this study is only 23 inches, against 27 inches for those affected by heart rot. It is probable that, as in the case of germination, the rot ordinarily has no material effect.

Spike tops show a yield only one-half as great as that given for healthy yellow pines. This is probably due to a reduction in the size of the living crown. The living branches of spike tops are frequently heavily laden with cones, and it is probable that the injury causing the death of the top acts as a stimulus upon cone production, as upon the vitality of the seeds.

The influence of basal burns upon yield is not fully demonstrated. The yellow pine bearing fire scars shows an average yield of 0.3 bushel more than the healthy yellow pine; but a comparison of diameters shows that the scarred trees have an average diameter of 25 inches against 23 inches for the healthy ones. Whether the greater yield is due entirely to the greater size of the burned trees or whether the influence of the burns is also a factor, can not be determined from the data at hand.

The yield of trees suffering from suppression and attacks of bark beetle and mistletoe are all much below that of normal trees of their class. While the number of trees in each case is too small to furnish reliable data, the results are very significant.

The yield decreases as the density of the stand increases. The average yield of cones per tree for open, medium, and dense stands are 1.8, 1.1, and 0.7 bushels, respectively. This difference is undoubtedly due mainly to a difference in crown development as influenced by growing space. Since western yellow pine is very light demanding, the trees growing in close stands have narrow, short crowns, and only those branches which are exposed to full or nearly full sunlight bear any cones whatever. Therefore, although the seed produced by a tree in a close stand is of higher quality than that produced in the open, as indicated by the germination tests, the total seed-producing capacity of a tree in a close stand is much lower.

APPLICATION OF CONCLUSIONS.

Blackjacks are the most desirable trees to leave for regeneration in cutting. The blackjack has the advantage over the older yellow pine in point of seed quality, and also in the rate of growth. A blackjack left for a future cutting will increase rapidly in volume, while a yellow pine will increase but slowly or even deteriorate.

In marking for cutting in the yellow-pine type it is the invariable practice to leave all healthy blackjacks, and also to leave a sufficient number of yellow pines to insure a second cut in about 30 to 50 years. But if a second cut were the only consideration in marking there would not always be sufficient provision made for seed

trees; because the trees left for a second cut do not have to be very evenly distributed over the area. Thus, one quarter section may contain an abundance of blackjack and yellow pine suitable to leave for a second cut, whereas an adjoining quarter section may contain mostly yellow pine which can be cut now, and very few seed-bearing blackjacks. Trees below 16 inches in diameter breast-high usually bear only small quantities of seed, and hence will not figure materially in the seed crop for the next few years. Therefore, if immediate reproduction is desired, wherever there are not enough seed-bearing blackjacks the deficiency must be made up from the youngest and best developed yellow pines available, even though not needed for a second cut. The number of trees per acre needed for seed purposes varies greatly with size and condition; on the average, from 3 to 5 yellow pines and about twice as many blackjacks (over 16 inches diameter breast-high) are required.

Spike tops and burned or decayed trees should always be cut, unless greatly needed for seed purposes. While such trees usually have a high seed-bearing capacity, to leave them standing until a second cut can be made involves merchantable deterioration or total loss. The risk in the case of light burns is comparatively small, but in the case of spike top and decay loss is certain. Since in extreme cases, however, it becomes necessary to leave defective trees for want of anything better, it is well to know that, unless too far gone, such trees can be expected to produce large quantities of superior seed for a number of years.[1]

Trees infested by mistletoe or bark beetles, even though not killed, are of little value for seed, and should be cut as being a menace to the forest. (Instructions in regard to the proper disposal of trees attacked by bark beetles are given in Bulletin 83, Part I, U. S. Department of Agriculture, Bureau of Entomology.) An exception to this rule may be permissible in the case of mistletoe, when the trees are isolated and when the attack is slight, but not in the case of bark-beetle infestation. Further investigations in regard to the effect of mistletoe and bark beetles are needed.

Isolated trees are preferable to those in close stands; first, because they usually have larger crowns; and second, because they are more windfirm.

For seed collecting, young trees are most desirable from a purely technical standpoint on account of the high vitality of their seed; but in practice, older trees are preferable on account of their heavier yield, and because the seed from such trees can often be collected cheaply in connection with logging operations. Such defects as spike top, burns, or heart rot are not objectionable; but trees affected by insects or mistletoe should be avoided.

[1] Records have been established to determine how long such trees will persist.

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HENRY S. GRAVES, Forester.

UTAH JUNIPER IN CENTRAL ARIZONA.

BY

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Collaborators.

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UTAH JUNIPER IN CENTRAL ARIZONA.

PURPOSE OF THE STUDY.

Utah juniper (*Juniperus utahensis*) is the most important tree in the woodland forest of central Arizona. The woodland forest itself is of value chiefly because the scarcity of timber in the region of its occurrence brings its products into great demand for fuel, fence posts, and other small but important uses. Hitherto it has commonly been known as the woodland type—a misuse of the word "type" that has frequently led to confusion, since, properly speaking, the forest is composed of a number of types as distinct as the western yellow pine type, the eastern white pine type, or any other forest type. In this and other publications of the Forest Service, therefore, the term "woodland forest" will be used in place of "woodland type."

In making the study of Utah juniper, the results of which are given in this circular, the aim was to secure as many data as the time allowed for the investigation would permit, on (1) the silvical characteristics which most influence reproduction, (2) rate of growth, and (3) volume. The study was made in and near the Tusayan National Forest, Ariz. While the data gathered are insufficient as a basis for final conclusions, they should serve, until more detailed information can be had, as a general guide in the management of the Utah juniper type.

DISTRIBUTION.

Utah juniper is one of the most abundant and generally distributed trees from the western foothills of the Wasatch Mountains, in eastern Utah, to southeastern California, and throughout northern and central Arizona, western Colorado, and southern Wyoming. It is distinctly a tree of the high plateau region bordering the desert, growing at altitudes between 4,800 and 7,000 feet, with the best stands between 5,500 and 6,500 feet. It attains its best individual development and grows in heaviest stand in Coconino County, Ariz., directly west of the railroad from Williams to the Grand Canyon.

NOTE.—The work on volume and yield is by Walter Mulford; all other parts are by Frank J. Phillips, except as otherwise noted.

CLIMATIC REQUIREMENTS.

Like the other species which go to make up the woodland forests of Arizona and New Mexico, Utah juniper grows in regions where the average annual rainfall is from 14 to 18 inches, usually nearer

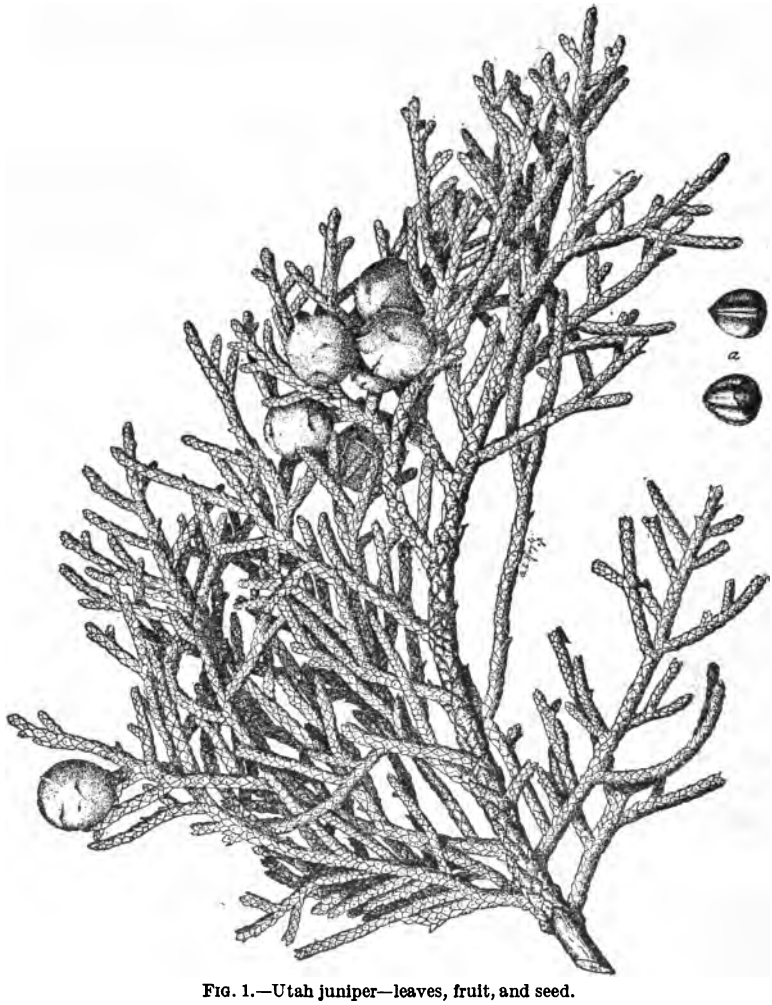

FIG. 1.—Utah juniper—leaves, fruit, and seed.

the first, with a minimum of from 9 to 10 inches and a maximum of about 25 inches. Most of this comes in July and August and is usually torrential.

BOTANICAL CHARACTERISTICS.[1]

The leaves of Utah juniper are minute, sharp, scale-like, and pale yellowish-green; generally without a pit (gland) on the back; mostly in alternately opposite pairs, closely overlapping each other in 4

[1] From Forest Service Bulletin, Forest Trees of the Pacific Slope, by George B. Sudworth.

rows on the slender, stiff-looking twigs; sometimes in 6 rows with three leaves at a point. The leaves of vigorous leading shoots are much larger and are keenly pointed, while those of seedlings are needle-like. The bark of larger twigs which have shed their leaves is pale reddish-brown and scaly. Ripe berries, matured in the fall of the second year, are covered with a whitish bloom which, when rubbed off, exposes a smooth, red-brown, tough skin. They usually contain one seed (occasionally two), pointed at the end, prominently and sharply angled, and marked nearly to the top by what appears to be scale-like basal covering (the seed scar), to which the thin, sweet pulp is attached. The surface of the berries shows projecting points (ends of minute flower scales). Seed leaves, usually 5 in number, but ranging from 4 to 6, are pointed.

SILVICAL CHARACTERISTICS.

SITE REQUIREMENTS AND ASSOCIATED SPECIES.

In the region studied, pure stands of Utah juniper are found on rolling slopes and hills with a very fine adobe soil, thickly studded with large malpais (basaltic lava) rocks. Interspersed with the trees are many individuals or groups of buckbrush (*Cowania mexicana*), probably indicating the presence of a large amount of lime. The ground cover consists of many annuals and perennials, the most common a coarse bunch grass. The trees attain their best development in the canyons, reaching a diameter of 3 feet and a height of from 30 to 35 feet.

Near the desert pure stands of Utah juniper are usually confined to hilltops covered with malpais outcrops, or to adobe valleys where there appears to be more than the usual amount of moisture. It also grows in the malpais canyons leading out to the desert, usually with a few specimens of *Morus celtidifolia* and *Celtis reticulata* and numerous shrubs. On all the more unfavorable sites the limits of the stand are sharply defined by surrounding adobe clays of fine texture.

On limestone formations about Grand Canyon, covered with shallow soil, Utah juniper is mixed with piñon. Two sample plots of one-half acre each showed an average of 68 per cent piñon and 32 per cent Utah juniper. While this is the condition on the high plateau which slopes to the southwest, on that sloping toward the east various-sized groups of Utah juniper and piñon are interspersed among other groups of western yellow pine and Gambel oak.

In the region west of Cedar Glade, Utah juniper is found in pure stands between approximate elevations of 5,100 and 5,500 feet, but from 300 to 800 feet higher up it grows in mixture with single-leaf piñon (*Pinus monophylla*). Here, though the latter seems to be

confined to sandstone and limestone areas, juniper grows on malpais as well. The two species have been found in close mixture elsewhere in Arizona, usually with a small amount of Rocky Mountain red cedar also present. Near Ash Fork and at Gleed a few specimens of alligator juniper were observed in mixture, and at Mount Picacho a few New Mexican locusts. The canyons, naturally, present the greatest variety of trees and shrubs in mixture with Utah juniper. In the canyons about Gleed and Puntenny *Quercus chrysolepis* is the most common of these.

From the desert to regions of pure western yellow pine, then, the character of the stand of Utah juniper may be classified as follows:

(*a*) Widely scattered individuals encroaching on the desert.

(*b*) Island stands encroaching on the desert, usually on malpais outcrops.

(*c*) Pure stands over large areas, chiefly on mixed malpais and adobe sites.

(*d*) In close mixture with piñon (*Pinus edulis*), or more rarely with *Pinus monophylla*.

(*e*) In groups with piñon, interspersed with other groups of western yellow pine and Gambel oak.

Near the desert the species gains foothold through reproduction beneath the crowns of early scattered trees, resulting in even a more marked grouping than on better sites. In pure stands the trees occur in small, evenly distributed groups, exhibiting wide variation in yield, which, however, appears comparatively uniform when taken for large areas. The two classes of mixed stands form transitional stages between the pure stands of Utah juniper in the Aubrey Cliffs region and the nearly pure stands of western yellow pine in the San Francisco Peaks.

STEM AND CROWN.

The tendency to fork is more pronounced with Utah juniper than with any other prominent species of the woodland forest. Forking occurs usually at the surface of the ground, though sometimes at from 1 to 2 feet above. Mature trees rarely have a regular leader or a clear length of more than 3 or 4 feet. The growth of the entire tree is, in fact, exceedingly crooked.

When young the tree is roughly conical in form, and during middle age distinctly globular. In the veteran stage the crown is ragged and stag-headed, with many dead twigs at the ends of growing shoots. At middle age the crown is about as broad as long, while in old trees the width is slightly greater than the height.

On exposed sites, such as malpais outcrops and hilltops, the tree shows the effect of prevailing southwest winds by leaning slightly to the northeast. The tendency was especially evident in the "island"

stands between Gleed and Mount Picacho, and to a less degree on hilltops near the Grand Canyon. On poor sites near Mount Picacho the branches were somewhat longer on the northeast side of the trees than to windward, and the crowns were from 5 to 25 feet broader than long.

ROOT SYSTEM.

The most marked characteristics of the root system of Utah juniper seedlings, as observed during a study on the malpais site at Gleed, are the exceptionally long taproots on even the smallest plants, and the presence of mychoriza. The latter seem most abundant from 1.5 to 10 or more inches below ground, and on seedlings with the thriftiest growth. Seedling roots are distinguished by the deep maroon color of the inner bark, by the slight taper of the laterals, and by the presence of only a moderate number of root hairs. The taproot tends to grow straight down to the rock substratum, at a depth of from 18 to 36 inches, and when that is reached to turn abruptly at right angles. Table 1 shows the length of taproot for different ages and heights of seedlings.

TABLE 1.—*Length of taproot in seedlings of different ages and heights.*

Age.	Height.	Length of taproot.
Years.	*Inches.*	*Inches.*
1	1.3	10.5
2	3.3	15.4
3	6.3	19.4
4	9.7	21.8
5	13.2	23.9
6	16.7	26.0
7	19.8	26.0

Only one healthy mature tree was observed to have been uprooted by the wind. A number of dead trees, however, had been blown down, and these furnished data on the root systems of old trees. Though the largest root almost invariably goes straight down to the substratum, the root system as a whole is distinctly lateral. The roots, usually from three to six in number, vary in diameter from 4 to 15 inches at their junction with the trunk. On the usual malpais formation the root system is seldom more than 2 feet deep, extending to the edge of the crown, or, on exposed sites. to from 10 to 20 feet beyond.

REPRODUCTION.

Utah juniper, like most of the junipers, is a prolific seeder in open stands. The best seed crops are nearly always produced on the poorer sites, where the trees are usually loaded with berries, sometimes as much as 2 or 3 bushels. On better sites, even in the same locality,

only a few trees bear seed, and these rarely more than from 1 to 3 quarts. Some seed may be secured from one locality or another every year, but nowhere does the species fruit at regular intervals. Most of the berries are eaten by birds, predatory animals, and rodents.

In pure stands reproduction occurs chiefly under the crowns of large mature trees. Results from typical sample plots of 1 acre each are given in Table 2. The figures in the last four columns are for seedlings in partial shade.

TABLE 2.—*Proportion of seedlings in open and under partial shade.*

Total.	Number seedlings in open.	Number of seedlings under partial shade.	Per cent on north.	Per cent on south.	Per cent on east.	Per cent on west.
172	40	132	27	34	24	15
230	51	179	31	30	18	21

Reproduction under shade on the areas studied was confined very largely to a limited zone directly beneath the outer edge of the crown. Under trees with a crown radius up to 12 feet, 76 per cent of the reproduction occurred in a zone the inner limit of which was 2 feet within and the outer limit 1 foot beyond the crown edge. Outside of this zone was 13 per cent of the total reproduction, while between the inner edge of the zone and the trunk of the tree was 11 per cent. Where the tree crowns had an average radius of from 13 to 17 feet, 81 per cent of the reproduction occurred in a zone with an inner limit 2 feet inside and an outer limit 2 feet beyond the crown edge, the greater breadth of zone being probably due to a more irregular crown. Outside this zone occurred 12 per cent of the seedlings and inside only 7 per cent.

INJURIES.

FUNGI AND MISTLETOE.[1]

Utah juniper in the vicinity of Gleed is badly affected with rot caused by a species of fungus, *Fomes* (*Pyropolyporus*) *texanus*, which attacks the heartwood of older living trees, gaining entrance through wounds and fire scars. This appears to be worse at the base of the tree, and often extends into the roots to a depth of from 1 to 2 feet or more beneath the surface. A sample count of 100 trees on a hilltop and of another hundred in an arroyo approximately 100 feet lower in elevation gave results shown in Table 3.

[1] The greater part of the material under this head is contributed by Dr. George G. Hedgcock, Office of Investigations in Forest Pathology, Bureau of Plant Industry.

FIG. 1.—A UTAH JUNIPER FORKING AT BREASTHEIGHT. THE BUTT DIAMETER IS 21 INCHES.

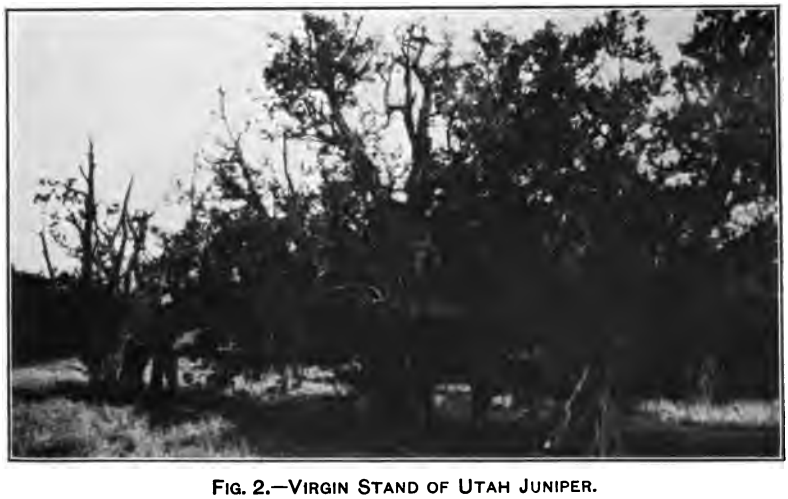

FIG. 2.—VIRGIN STAND OF UTAH JUNIPER.

FIG. 3.—IRREGULARITY OF UTAH JUNIPER CORDWOOD STICKS.

TABLE 3.—*Percentage of trees affected by rot.*

Locality.	Sound.	Slight butt rot.	Severe butt rot.	Total butt rot.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Hill	77	12	11	23
Arroyo	69	13	18	31

The apparent relative soundness on hill sites, though suggestive, is based on too little data to be conclusive.

A species of rust, *Gymnosporangium kernianum* Bethel, attacks the young twigs of some trees, causing the formation of dense "witches' brooms." This stunts the growth of the trees attacked, but rarely kills them. A second species, *Gymnosporangium gracilens* (Peck) Kern and Bethel, attacks the limbs, occasionally forming fusiform swellings. The limbs attacked often die, and sometimes the trees also. A third species, *Gymnosporangium nelsoni* Arth., attacks the twigs, forming woody, globose galls, sometimes densely aggregated, and, when numerous, stunting the trees. A fourth species, *Gymnosporangium inconspicuum* Kern, attacks the younger twigs between the leaves, causing the latter to turn yellow and injuring the trees whenever the attack is severe.

In many localities, especially on poorer soils and exposed slopes and ridges, Utah juniper is attacked by the mistletoe *Phoradendron juniperum* Engelm., the seeds of which adhere to the younger twigs, upon which they germinate, and the roots penetrate the bark and secure a hold in the cambium. After a few years a large dense cluster of the mistletoe is formed on the limb, which, deprived of sufficient nutriment beyond the point of attack, finally dies. In extreme cases as many as 50 mistletoe plants form on a single tree, and by depriving so many limbs of nutrition bring about its death by starvation.

FIRE.

Though in seasons of drought severe fires have occurred in the woodland forest during March and April, the fire danger is greatest in May and June. Surface fires are the most common, but crown fires sometimes occur. In a mixed stand near Grand Canyon the different species suffered in the following degree, the most affected first:

Piñon ..... *Pinus edulis.*
Western yellow pine ..... *Pinus ponderosa.*
Utah juniper ..... *Juniperus utahensis.*

Gambel oak (*Quercus gambelii*) suffers nearly as much as piñon of equal size, but its excellent sprouting capacity enables it to renew the stand. In immediate damage buckbrush (*Cowania mexicana*) suffered less than the Gambel oak.

SHEEP AND CATTLE.

Where grass is plentiful and the range grazed moderately, reproduction suffers little damage from sheep and cattle. But in bad years, in fenced private pastures or along traveled routes between the summer and winter ranges, the reproduction often suffers, especially from sheep. On three sample plots taken near Gleed the first, situated immediately south of a watering place where grazing was severe, showed that 93 per cent of the young trees had been injured by sheep; the second, taken 80 rods to the south of the dam, showed 73.7 per cent injured; and the third, taken about 3 miles northwest of Gleed, 53.4 per cent. These counts were made on trees less than 6 feet tall. With some of these injury had consisted in loss of leaders, though this rarely occurs after the tree has reached a height of 3½ feet, and usually not after 2½ feet. Reproduction protected by brush showed far less injury than that in the open. On cut-over areas, where brush had been scattered over the seedlings, only 15 per cent showed injury, while in the open 81 per cent had been grazed back. These counts included seedlings up to 3 feet tall.

GROWTH.

In the study of growth, which was confined to the malpais formation north of Gleed, the problem of age determination was a difficult one. Stumps of mature trees, one-half hour after cutting, would show seasoning checks, which rapidly increased in number and size for an hour or two, and then gradually for the next two days. The seasoning process also rendered the rings in the heartwood less distinct. Chiseling the sawed stumps immediately after felling, moistening the freshly chiseled surface, and counting the rings as soon as possible, gave the best results.

Utah juniper presents other difficulties in accurate ring counting. In many cases the spring wood and summer wood are defined by two distinct lines rather than by the usual zones of tissue of varying density. These distinct lines are likely to be false rings, more than ordinarily distinct, and in every case were so regarded. Every tree examined showed split [1] rings, which seem to be common to many woodland species. Often these divided gradually, the split going nearly around the stem; in other cases the split was very abrupt, nearly encircling the stem; in still others several splits occurred in the same ring; while in a very few cases double splits were found.

[1] From studies made on this species and other more rapid-growing ones, it would seem that split rings are in most cases due to the advanced growth of especially thrifty branches, since on small trees they often occur in succession in the same radius as some thrifty branch.

In order to trace rings for some distance on each side, a segment, varying from one-fifth to one-twentieth of the cross-section area, was chiseled on all trees, and occasionally ring counts were made on opposite sides of the tree to serve as a check.

In seedling analysis, trouble was also given by crescent-shaped areas of tissue of slightly darker or lighter shade than normal, which give a spiral appearance to the rings as seen in cross section. Dried seedlings often gave somewhat better general results than green ones, and counts made at the top of the root and within 1 inch from the ground were occasionally better than counts at the ground surface. A complete analysis often required an average age between sections one inch or more above and below the desired section rather than a determination at the exact point. In all cases the current year's growth was determined by leader growth rather than by ring counts. Where seedlings occurred in litter one inch or more in depth, the start of the growing point was considered to be at the bottom of the litter.

Seedlings were classified into those growing in the open and in shade, and those injured by grazing and uninjured. Table 4 gives the height.

TABLE 4.—*Height growth of Utah juniper seedlings.*

Age.	In the open.		In shade.		Age.	In the open.		In shade.	
	Uninjured.	Injured by grazing.	Uninjured.	Injured by grazing.		Uninjured.	Injured by grazing.	Uninjured.	Injured by grazing.
Years.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Years.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
1	1.3	.....	1.1	.....	21	.....	.....	31.5	16.0
2	3.3	.....	2.4	.....	22	.....	.....	33.0	16.7
3	6.3	3.6	3.6	.....	23	.....	.....	34.5	17.4
4	9.7	5.7	4.9	3.8	24	.....	.....	36.0	18.1
5	13.2	8.1	6.3	5.0	25	.....	.....	37.5	18.8
6	16.7	10.9	7.7	6.1	26	.....	.....	39.0	19.7
7	19.8	13.8	9.1	7.3	27	.....	.....	40.4	20.6
8	22.7	17.0	10.6	8.4	28	.....	.....	41.8	21.5
9	25.1	19.8	12.1	9.3	29	.....	.....	43.2	22.4
10	27.2	22.2	13.6	10.2	30	.....	.....	44.6	23.3
11	29.1	24.2	15.2	10.9	31	.....	.....	.....	24.2
12	30.9	25.8	16.8	11.6	32	.....	.....	.....	25.1
13	32.2	27.4	18.4	12.2	33	.....	.....	.....	25.8
14	33.5	28.9	20.0	12.6	34	.....	.....	.....	26.6
15	34.1	30.4	21.7	13.0	35	.....	.....	.....	27.5
16	35.7	31.9	23.4	13.4	36	.....	.....	.....	28.4
17	36.7	33.4	25.1	13.9	37	.....	.....	.....	29.4
18	.....	.....	26.7	14.4	38	.....	.....	.....	30.3
19	.....	.....	28.4	14.9	39	.....	.....	.....	31.2
20	.....	.....	30.0	15.4	40	.....	.....	.....	32.0

In selecting large trees for measurement, care was taken to choose only those for which all conditions of growth, except light, were as far as possible the same. In Table 5 the trees are classified as grown in the open and in partial shade.

TABLE 5.—*Growth of Utah juniper in open and under shade.*

Age.	Diameter 1 foot above ground.		Height.		Age.	Diameter 1 foot above ground.		Height.	
	Grown in open.	Grown in partial shade.	Grown in open.	Grown in partial shade.		Grown in open.	Grown in partial shade.	Grown in open.	Grown in partial shade.
Years.	*Inches.*	*Inches.*	*Feet.*	*Feet.*	*Years.*	*Inches.*	*Inches.*	*Feet.*	*Feet.*
10	0.6	0.40	2.1	1.3	120	7.95	6.25	15.3	14.2
20	1.2	.85	3.9	2.7	130	8.6	6.8	15.8	14.8
30	1.8	1.3	5.7	4.1	140	9.25	7.3	16.2	15.4
40	2.45	1.8	7.4	5.4	150	9.85	7.8	16.6	16.0
50	3.1	2.3	9.1	6.7	160	10.4	8.25	17.1	16.5
60	3.8	2.85	10.5	8.0	170	10.95	8.65	17.6	17.0
70	4.5	3.4	11.7	9.2	180	11.45	9.05	18.0	17.5
80	5.2	3.95	12.7	10.4	190	11.95	9.45	18.5	18.0
90	5.9	4.55	13.5	11.5	200	12.4	9.85	18.9	18.5
100	6.6	5.15	14.3	12.3	210	12.85	10.25	19.4	18.9
110	7.3	5.7	14.8	13.4					

Table 5 shows that the effect of shade on both height and diameter growth, but especially the former, was small. This does not mean, however, that Utah juniper is tolerant, but rather that the shade of the mother tree is scanty. It also brings out clearly the remarkably slow growth of the species, which reaches a diameter of only 12.85 inches and a height of only 19.4 feet in 210 years.

The great care necessary in the selection of both seedlings and mature trees for measurement makes the bases for Tables 4 and 5 somewhat inadequate. Both tables are, however, as accurate as existing conditions would permit.

VOLUME.

CONSTRUCTION AND USE OF VOLUME TABLES.

Utah juniper's irregular form makes accurate determination of volume exceedingly difficult. Its tendency to divide into two or more stems at or near the ground prevents the use of breastheight as the point at which to measure diameter. The reference diameter selected, therefore, is that outside the bark 1 foot above the mineral soil. Even this is not altogether satisfactory, since the irregular shape of the butt, often accentuated by irregularities due to root swelling and by ridges formed by low branches, makes exact measurement of the diameter difficult, while, even if accurate measurement is possible, variation in number and size of stems above the point of measurement brings about irregularities in volume between trees of the same butt diameter and height. Yet notwithstanding these drawbacks, the butt diameter, as that selected will be termed, seemed the only possible basis on which to compute volume.

The forking habit of Utah juniper made it desirable in measuring volume to consider each of the larger stems in a several-stemmed tree as a separate tree. However. it was necessary to adopt certain

FIG. 1.—A TWO-STEMMED UTAH JUNIPER CONSIDERED AS A SINGLE TREE. SMALLER STEM IS LESS THAN 8 INCHES IN DIAMETER.

FIG. 2.—A THREE-STEMMED TREE.

arbitrary rules in respect to what constituted a separate stem. To be considered as such, it was stipulated that a separate stem of a several-stemmed tree must divide from the trunk at some point between the mineral soil and 1 foot above it, the latter limit to apply to the center of its junction with the trunk, and must have a butt diameter of not less than 8 inches. Stems which separated from the main trunk below the mineral soil were considered as separate trees, no matter what their diameter. Stems which divided from the main trunk at a point more than 1 foot above the mineral soil and those with a butt diameter of less than 8 inches which separated from it within 1 foot of the ground, were considered as parts of the larger stems and their volumes not computed separately. A tree with two or more stems branching above the mineral soil and within 1 foot of the ground, all less than 8 inches in diameter, was considered as a single tree having a diameter equal to that of the largest stem. Any tree with a single stem, however bushy and irregular in form, was considered as a single tree.

In measuring height, the actual length of a leaning tree or separate stem was taken, not the vertical distance of its top above the ground. Separate stems often diverge at so wide an angle that the top of one may be only 6 feet above the ground, though its actual length is 10 feet.

The possibility of error in a comparison of the volume of a single-stem tree with that of a separate stem of a forked tree led to the preparation of separate volume tables for the two classes. The difference between the two tables proved, however, to be both slight and irregular, and they were therefore combined into one.

Accurate volumes in cordwood for Utah juniper are also difficult to obtain owing to the great variation in volume between cordwood sticks of the same middle diameter. Almost any stick from Utah juniper is likely to be exceedingly crooked, as well as irregular in cross section, while usually there are so many small branches to be trimmed that stubs are left on the sticks, which prevent close piling.

Because of the sources of inaccuracy mentioned, volume tables for Utah juniper can at best be only approximate. Applied to single or to only a few trees, or in small cordwood sales, there is likelihood of serious error. Accuracy will increase, however, with the number of trees.

Tables 6 and 7 give volumes for Utah juniper in cubic feet and cords, respectively. The measurements on which the tables are based were made in two places near Ash Fork, Ariz., on medium sites. In applying the tables it will be necessary, of course, to follow strictly the methods of classifying stems and of measuring height used in their preparation. If, however, a large proportion of the trees in a stand divide within 1 foot of the ground into stems, most

of which are less than 8 inches in diameter, the rule to disregard such stems should not hold. Instead, each of the small stems should be considered as a separate tree and its volume determined from Table 6, or else from Table 9. The first method is quicker, but less accurate, since the values obtained will probably be too high.

In using the volume tables it will be necessary to learn to estimate both height and butt diameter, instead of actually measuring them, since the inconvenience entailed by doing the latter with a low-branching tree like the Utah juniper is great. In determining the point 1 foot above the ground on a side stem the estimate or measurement should follow the main stem to the center of the junction and then continue out on the fork.

Although the volume tables are for round wood, they will apply as well where large sticks are split. If nearly all the wood is split, the tables will tend to be conservative.

VOLUME IN CUBIC FEET AND CORDS.

Volume in cordwood was obtained by dividing the volume in cubic feet, computed on the basis of middle diameter outside bark and length, of each stick cut from a tree by 62, the average number of cubic feet per cord. This converting factor was obtained from measurements of approximately 62 cords, in about two-thirds of which the larger sticks were split and in the remainder none of the sticks. The average number of sticks per cord was, in the first case, 176 and in the second 141. The average diameter of the sticks was about 4 inches. Since the converting factor, 62, is based on average size trees, the table, when applied to very small trees, will give values too low and when applied to very large trees too high. The inaccuracies are not great, however, even in the case of a single tree, and will tend to offset each other in an estimate of a number of trees.

TABLE 6.—*Volume of cordwood in stem and branches, in cubic feet.*

Diameter 1 foot above ground.	Height in feet.			Diameter 1 foot above ground.	Height in feet.		
	10	15	20		10	15	20
	Volume solid contents in stem and branches, cubic feet.				Volume solid contents in stem and branches, cubic feet.		
Inches.				*Inches.*			
3	0.2	.....	.....	14	7.0	8.6	10.7
4	.4	.....	.....	15	8.1	10.0	12.2
5	.7	0.8	.....	16	9.3	11.4	13.8
6	1.1	1.3	.....	17	.....	12.8	15.5
7	1.5	1.9	2.4	18	.....	11.4	17.2
8	2.0	2.6	3.2	19	.....	16.0	19.1
9	2.6	3.4	4.3	20	.....	17.6	21.0
10	3.3	4.3	5.4	21	.....	19.4	22.9
11	4.1	5.3	6.6	22	.....	21.2	24.8
12	5.0	6.3	7.9	23	.....	.....	26.7
13	5.9	7.4	9.3				

[1] Based on measurements of 495 trees.

TABLE 7.—*Volume of Utah juniper, stem and branches, in cordwood.*[1]

Diameter 1 foot above ground.	Height in feet.			Diameter 1 foot above ground.	Height in feet.		
	10	15	20		10	15	20
Inches.	*Cords.*	*Cords.*	*Cords.*	*Inches.*	*Cords.*	*Cords.*	*Cords.*
3	0.003	.....	.....	14	0.113	0.139	0.173
4	.006	.....	.....	15	.131	.161	.197
5	.011	0.013	.....	16	.150	.184	.223
6	.018	.021	.....	17	.....	.206	.250
7	.024	.031	0.039	18	.....	.232	.277
8	.032	.042	.052	19	.....	.258	.308
9	.042	.055	.069	20	.....	.284	.339
10	.053	.069	.087	21	.....	.313	.369
11	.066	.085	.106	22	.....	.342	.400
12	.081	.102	.127	23	.....	.....	.430
13	.095	.119	.150				

[1] Basis, 495 trees.

SUPPLEMENTARY TABLES.

Since, with Utah juniper, diameters are measured outside the bark, it was necessary to find the average width of bark for trees of different diameters inside bark 1 foot from the ground. This is shown in Table 8. The difference between widths of bark at the stump and on the upper stems and branches was found to be negligible.

TABLE 8.—*Width of bark in Utah juniper.*

Diameter inside bark.	Average width of bark.
Inches.	*Inch.*
2	0.2
3- 5	.3
6-12	.4
13-21	.5

If the number of trees to be estimated is too few for accurate results to be gotten from the use of Tables 6 and 7, Table 9 may be useful. It is also useful in determining the volumes of trees with many stems under 8 inches in diameter.

TABLE 9.—*Volume of cordwood sticks, Utah juniper.*

Middle diameter outside bark 4-foot sticks.	Volume of stick.	Number of sticks in 1 cord.	Middle diameter outside bark 4-foot sticks.	Volume of stick.	Number of sticks in 1 cord.
Inches.	*Cord.*		*Inches.*	*Cord.*	
3	0.003	333	10	0.035	29
4	.006	166	11	.043	23
5	.009	111	12	.051	20
6	.013	76	13	.059	17
7	.017	59	14	.069	14
8	.023	44	15	.079	13
9	.028	35			

In using the table, count the number of 4-foot sticks in the stem and branches and estimate the diameter outside bark of the sticks of average size. The diameter of each separate stick need not be estimated. With large trees the table will be more accurate if the cordwood sticks are divided into large and small ones, and the average diameter of each class estimated. In any case, however, the table can be used for only a rough estimate of volume, since there is likelihood of error in estimating the average diameter, which, moreover is not an accurate basis on which to compute the average volume of the sticks. Since the converting factor of 62 cubic feet of wood per cord used in constructing the table is based on the average contents of cords containing sticks of all sizes, strictly accurate results will not be obtained when, for example, 4-inch sticks are compared with 14-inch sticks. However, since the average size of all the cordwood sticks cut from a stand of Utah juniper will usually be about the same as that of the sticks used in obtaining the ratio, discrepancies will not be great.

Table 10 may serve as a general guide in determining the number of cordwood sticks to be obtained from average trees of different heights and diameters. It gives the total number of cordwood sticks in the stem and branches above a diameter limit of 2 inches outside the bark at the middle of the stick, or of about 1.5 inches outside the bark at the small end of the stick.

TABLE 10.—*Number of cordwood sticks in trees of different diameters and heights, Utah juniper.*[1]

Diameter 1 foot above ground.	Height.	Number of cordwood sticks.	Diameter 1 foot above ground.	Height.	Number of cordwood sticks.
Inches.	*Feet.*		*Inches.*	*Feet.*	
3	9.0	1.0	15	17.5	16.9
4	10.0	1.6	16	17.9	19.1
5	10.9	2.2	17	18.3	21.3
6	11.8	3.1	18	18.6	23.5
7	12.7	4.0	19	18.9	25.8
8	13.5	5.2	20	19.2	28.1
9	14.3	6.4	21	19.5	30.4
10	15.0	7.8	22	19.8	32.7
11	15.6	9.4	23	20.1	35.0
12	16.1	11.1	24	20.4	37.4
13	16.6	13.0	25	20.6	39.8
14	17.1	14.9	26	20.8	40.2

[1] Based on measurements of 495 trees.

Table 11 gives the number of round posts, 7 feet long, which could have been cut from trees of different diameters in the region studied. The small number of posts per tree, especially in the larger trees, is strikingly shown. The table is derived from estimates, not from posts actually taken out, since all the wood was cut into cordwood. In many places, however, the yield of posts from the larger trees would

probably be much higher than indicated here. The number of posts which can be cut from trees of given sizes varies so in different localities, both because of differences in market requirements and of variation in percentage of stems and branches which will make good posts, that the table can not be relied upon for localities other than those in which the data were gathered.

TABLE 11.—*Utah juniper, yield of posts per tree on the areas studied.*

Diameter 1 foot above ground.	Percentage of trees containing one or more posts.	Average yield of posts per tree (average based only on such trees as contain one or more posts).
Inches.	*Per cent.*	
5- 9	36	1.1
10–14	34	1.5
15–19	31	1.0
20–24	25	1.0

The grading of posts is not uniform. The classification used in the region studied was: A first-class post must be straight, with a top diameter of at least 3½ inches; a second-class post has the same top diameter, but may be somewhat crooked; a third-class post must have a top diameter of at least 2 inches and must be straight. On this basis about 34 per cent of the posts were of class 1; 42 per cent of class 2; and 24 per cent of class 3.

Table 12 should be of help in estimating the cordwood to be derived from stands in which posts are to be cut. To determine this, the approximate amount of cordwood removed in the posts should be deducted from the total cordwood volume. The result will be the amount of cordwood which may be secured in addition to the posts. In constructing the table it was assumed that posts are 7 feet long, and that 1 cord equals 62 cubic feet.

TABLE 12.—*Amount of cordwood removed in posts, Utah juniper.*

Middle diameter of post outside bark.	Amount of cordwood removed in each post.	Approximate number of posts to 1 cord of wood.
Inches.	*Cord.*	
3	0.006	167
4	.010	100
5	.015	67
6	.022	45
7	.030	33
8	.039	26

YIELD.

In order to obtain an idea of the yield of Utah juniper per acre, measurements were made on seven sample plots of 1 acre each, on which the species occurred in practically pure stand. The results are given in Table 13.

TABLE 13.—*Number of trees per acre, Utah juniper.*

Diameter 1 foot above ground.	Number of trees per acre.[1]
Inches.	
3- 4	14
5- 7	28
8-10	31
11-13	23
14-16	15
Over 16	9
Total...	120

[1] Nearest whole number.

Since even the biggest trees of the stand are seldom more than from 15 to 20 feet high, the diameters may seem on the average surprisingly large. This, however, is due to the fact that the reference diameter is near the ground, instead of at breastheight.

The average yield per acre obtained from the seven sample plots was 662 cubic feet, or 10.7 cords (no deduction made for posts). The average yield of posts [1] was 30 of class 1, 24 of class 2, and 17 of class 3; a total of 71.

The variability in yield of Utah juniper was well illustrated when, in spite of the fact that the sample plots were selected as typical of each locality, the cordwood yield varied from 4.4 cords to 27.1 cords, and that in posts from 46 to 117. On private lands the average yield per acre varies from 8 to 20 cords. From 10 to 14 cords is probably a fair average for good stands and 20 cords is considered heavy.

This variability in yield will in all likelihood make it impossible, even with more complete data, to prepare yield tables, based on either type or density of stand, suitable for use on uncruised areas. A better method of estimating the yield of a given area is to estimate the heights and diameters of the trees on circular sample plots, or on strips, and apply the volume table (Table 9).

UTILIZATION.

By far the greater part of the Utah juniper cut is in the form of cordwood for local use. This is transported by wagon or on the backs of burros. Cutting is done, as a rule, by Mexicans, who prefer the ax to the saw, though they are seldom skillful with either. Sometimes

[1] For definition of classes of posts, see page 17.

a stick is cut in two from one side only; sometimes from both sides. The latter method was found to be the less wasteful, though either method wastes much more than the saw. Occasionally a saw is used for cutting the sticks into 4-foot lengths after the tree is felled.

On the National Forest stumps must not exceed 12 inches in height. On private lands the height of stumps ranges from 8 to 30 inches.

MANAGEMENT.

Adequate reproduction of Utah juniper is usually hard to get. What reproduction there is occurs mainly under the edges of tree crowns, and because of this, and the fact that it responds readily to an increase in light, trees selected for cutting should be those which have reproduction beneath them. Cuttings should not ordinarily be heavy, and only small openings should be made in the stand.

Where there is danger of injury from stock, adequate protection can usually be given to young trees by throwing brush over them. This should not be so thick, however, as to exclude light. The fire danger will be increased thereby to some extent, but on the National Forests this is not great.

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CONDITION OF EXPERIMENTAL CHESTNUT POLES IN THE WARREN-BUFFALO AND POUGHKEEPSIE-NEWTON SQUARE LINES AFTER FIVE AND EIGHT YEARS' SERVICE.

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CONDITION OF EXPERIMENTAL CHESTNUT POLES IN THE WARREN-BUFFALO AND POUGHKEEPSIE-NEWTON SQUARE LINES AFTER FIVE AND EIGHT YEARS' SERVICE.

PURPOSE OF THE CIRCULAR.

Forest Service Bulletin 84, "Preservative Treatment of Poles," describes experiments made by the Forest Service concerning the effect of the seasoning and preservative treatment of poles upon their durability. This circular, which supplements it, gives the results of inspections of two experimental lines five and eight years, respectively, after their establishment.

The two lines, built in cooperation with the American Telephone and Telegraph Co., are known as the Warren-Buffalo line and the Poughkeepsie-Newton Square line. In the former are 1,164 30-foot chestnut poles, set between Warren, Pa., and Dayton, N. Y.; in the latter are 72 30-foot chestnut poles, set near Flanders and Morris County Junction in northern New Jersey.

EXPERIMENTAL POLES IN THE WARREN-BUFFALO LINE.

PREPARATION.

The experimental poles for the Warren-Buffalo line were cut and peeled during 1902 and 1903, and delivered at stations near Thorndale, Pa., and Dover, N. J., where they were placed in single tiers on skids about 2 feet above the ground to season. In June and July, 1905, some were butt treated with various preservatives by the brush method, and others with coal-tar creosote by the open-tank method. The following extract from Forest Service Circular 104, "Brush and Tank Pole Treatments," by Carl G. Crawford, describes the two methods of treatment:

Brush treatment.—It is generally conceded that the portion of a pole most subject to decay is that between 2 and 8 feet from the butt—about 20 square feet. This part fails when the remainder is still in a good state of preservation. It was therefore selected for treatment.[1] When the pole is set the treated portion extends 2 feet above and 4 feet below the surface of the ground. From one to three coats were applied, according to directions received from the manufacturer. Most of the preservatives were heated to a temperature of

[1] It is believed at the present time that more satisfactory results will be secured by treating the entire butt to a height of from 1 to 2 feet above the ground line.

from 150° to 175° F. Particular attention was paid to filling all checks and knot holes and to working the preservative into the wood, thus protecting against decay those parts most subject to attack. Careful notes were made of the condition of the poles as regards checks, knot holes, etc. The amount of preservative absorbed by each pole was accurately determined by recording the weight of the preservative before and after each treatment. The temperature of the preservative both before and after the treatment was also noted and recorded. In addition holes were bored into different parts of the treated portions of the poles, and the depth to which the preservative penetrated was closely observed.

Open-tank treatment.—Creosote was poured into the tank until the poles were covered for a distance of about 8 feet from the butt, and was then heated to a temperature above the boiling point of water. This temperature was maintained until the air in the wood had been expanded and the water in the outer layers vaporized, and both, so far as possible, driven out. * * * The preservative was then allowed to cool, thus producing a partial vacuum by the contraction of the air and the condensation of the steam remaining in the wood. The poles remained in the cooling liquid while the preservative, under atmospheric pressure, was forced into the wood. The entire time consumed by each treatment was about 24 hours, during which the temperature of the preservative was above the boiling point of water for 8 or 9 hours.

* * * Each pole was weighed before being put into the tank and again immediately upon being taken out. In this manner the amount of preservative absorbed was determined. No account could be taken of the amount of moisture driven out of the wood during the time the preservative was heated above the boiling point of water, and therefore the amount actually absorbed may be slightly greater than appeared from the weights. However, since the seasoned poles were practically air dry the determinations are probably very nearly correct. In the case of the green poles, on the other hand, it is probable that the actual absorption was considerably greater than that shown.

The preservatives used, method of application, and absorption secured are given in Table 1.[1]

PLACEMENT IN LINE.

Six hundred and thirteen treated poles, together with 551 untreated seasoned and green poles, were placed during August and September, 1905, in the line of the American Telephone & Telegraph Co., between Warren, Pa., and Buffalo, N. Y. This line extends at times along roadsides, and at others through cultivated fields, woodlots, and meadows, giving a variety of soil conditions. Table 2 shows the plan for setting the poles. Owing to difficulties in delivering the poles along the line, about 30 per cent were set with no definite plan. The number of poles of each kind is given in Table 3.

[1] The analyses of the preservatives used are given in the appendix to Bulletin 84.

TABLE 1.—*Method of treatment of poles set in Warren-Buffalo line.*

Condition when set.[1]	Preservative used, sold as—	Method of treatment.	Absorption secured per pole.		
			Average.	Maximum.	Minimum.
			Pounds.	*Pounds.*	*Pounds.*
Green		Untreated			
Seasoned		do			
Do	Coal tar	Brush, 1 coat			
Do	Creolin	do	3.39	4.13	2.88
Do	do	Brush, 2 coats	7.60	10.63	5.5
Do	Wood creosote	Brush, 1 coat	2.42	3.63	1.75
Do	do	Brush, 2 coats	5.43	6.63	3.25
Do	S. P. F. carbolineum	Brush, 1 coat	3.55	5.13	1.38
Do	do	Brush, 2 coats	4.38	6.63	3.0
Do	Avenarius carbolineum	Brush, 1 coat	1.98	2.25	1.13
Do	do	Brush, 2 coats	4.52	6.63	2.5
Do	Coal-tar creosote	do	7.77	11.75	4.13
Do	do	Open-tank	22.41	44.0	8.0
Green	do	do	15.20	39.0	4.0

[1] Describes also the condition at the time the treatment was applied.

TABLE 2.—*Plan of setting experimental poles in Warren-Buffalo line.*

No. of pole.	Condition when set.	Preservative used, sold as—	Method of treatment.
1	Seasoned	Avenarius carbolineum	Brush.
2	do		Untreated.
3	do	Avenarius carbolineum	Brush.
4	Green		Untreated.
5	Seasoned	S. P. F. carbolineum	Brush.
6	do		Untreated.
7	do	S. P. F. carbolineum	Brush.
8	Green		Untreated.
9	Seasoned	Coal-tar creosote	Brush.
10	do		Untreated.
11	do	Coal-tar creosote	Brush.
12	Green		Untreated.
13	Seasoned	Coal-tar creosote	Open-tank.
14	do		Untreated.
15	do	Coal-tar creosote	Open-tank.
16	Green		Untreated.
17	Seasoned	Wood creosote	Brush.
18	do		Untreated.
19	do	Wood creosote	Brush.
20	Green		Untreated.
21	Seasoned	Coal-tar creosote	Open-tank.
22	do		Untreated.
23	do	Coal-tar creosote	Open-tank.
24	Green		Untreated.
25	Seasoned	Creolin	Brush.
26	do		Untreated.
27	do	Creolin	Brush.
28	Green		Untreated.
29	Seasoned	Coal tar	Brush.
30	do		Untreated.
31	do	Coal tar	Brush.
32	Green		Untreated.
33	do	Coal-tar creosote	Open-tank.
34	Seasoned		Untreated.

The above series was repeated 24 times, series No. 2 beginning with pole No. 35, series No. 3 with pole No. 69, etc.

TABLE 3.—*Condition of experimental poles in Warren-Buffalo line after five years' service.*

Condition when set.	Description of poles.			Condition of poles at or near ground line.		
	Preservative used, sold as—	Method of treatment.	Number of poles.	Affected with decay.		Average loss in circumference at ground line.
				Number.	*Per cent.*	*Inches.*
Green		Untreated	194	194	100.0	1.16
Seasoned		do	357	355	99.4	1.01
Do	Coal tar	Brush—1 coat	48	47	98.0	.95
Do	Creolin	do	16	16	100.0	.89
Do	do	Brush—2 coats	63	44	69.8	.42
Do	Wood creosote	Brush—1 coat	21	20	95.2	.43
Do	do	Brush—2 coats	49	12	24.0	.06
Do	S. P. F. carbolineum	Brush—1 coat	10	3	30.0	.10
Do	do	Brush—2 coats	67	9	13.4	.04
Do	Avenarius carbolineum	Brush—1 coat	8	2	25.0	.27
Do	do	Brush—2 coats	66	9	13.6	.04
Do	Coal-tar creosote	do	83	12	14.5	.02
Green	do	Open tank	29	0	.0	.0
Seasoned	do	do	153	1	.65	Negligible.

METHOD OF INSPECTION.

Five years after placement the poles were inspected by representatives of the American Telephone & Telegraph Co., the Bureau of Entomology, and the Forest Service.[1] The method of inspection was as follows:

After the soil was removed from the base of each pole to a depth of from 6 inches to 1 foot the circumference was measured at or close to the ground line. Since this measurement was made to determine the original circumference of the pole, which, unfortunately, had not been measured when the poles were set, the proper point at which to take the measurement was carefully selected. If loss by decay impaired the accuracy of the measurement, proper allowance was made in the figures recorded.

After the first measurement the pole was carefully examined with hatchet and prod for decay or insect injury. Decayed portions of the poles, if of any extent, were removed with the hatchet, and a second measurement of circumference was then made at the point of greatest decay. This was usually found to be at or near the point selected for the first measurement. Poles which appeared to be unaffected by decay, but which rang hollow when struck with a hatchet, were bored to determine how far decay had actually progressed. After inspection creosoted plugs were driven into the holes and the soil which had been removed from about the poles was replaced.

[1] The members of the inspection party were: Mr. R. F. Hosford and Mr. C. E. Taylor, American Telephone & Telegraph Co.; Mr. T. E. Snyder, Bureau of Entomology, U. S. Department of Agriculture; and Mr. C. P. Winslow, Forest Service. Mr. Hosford and Mr. Snyder were present at the inspection of only some of the poles.

COMPUTATION OF DATA.

The per cent of each class of poles affected with decay at or near the ground line and the average loss of circumference at that point were computed. In most cases the latter could be determined by averaging for all poles in the class the differences between the two circumference measurements for each pole. Often, however, the extent and position of the decayed area were such that the two measurements showed no appreciable difference. In other cases decay in the treated zone was confined to cant-hook or other mechanical scars. For a fair comparison, therefore, it was necessary to make allowance for such conditions, and the following procedure was carried out:

(1) Where decay at or near the ground line was so situated that the measurements of circumference with and without the decayed portions showed little or no difference, an appropriate loss of circumference was assumed. This assumed loss was determined by the amount and situation of the decay according to tables of the American Telephone & Telegraph Company.

(2) For every pole showing signs of decay at the ground line a loss of circumference of one-eighth inch or more was recorded.

(3) In one set of computations those poles which showed decay due only to mechanical injury were considered as sound. The results, however, were so similar to those obtained when all poles which showed decay at the ground line were considered that only the latter ones are given.

CONDITION OF EXPERIMENTAL POLES.

Table 3 gives, for each class of poles, the per cent affected with decay and the average loss in circumference at the ground line. Figure 1 presents the same data in graphic form. The more significant results are summarized on page 12. For a proper valuation of these results the following points should be noted:

The comparatively small number of poles treated with only one coat of some of the preservatives renders the results in their case less conclusive than where two coats were used.

Analyses made by the American Telephone & Telegraph Co. of two samples of creolin showed a water content, respectively, of 20 and 90 per cent. So great a variation in composition must detract, of course, from the value of the test, so far as this preservative is concerned.

Aside from decay at the ground line, the condition of the experimental poles at the time of inspection was good. Many were slightly affected with sap rot in portions not influenced by soil moisture, and from some the outer fibers were peeling off. These trivial defects,

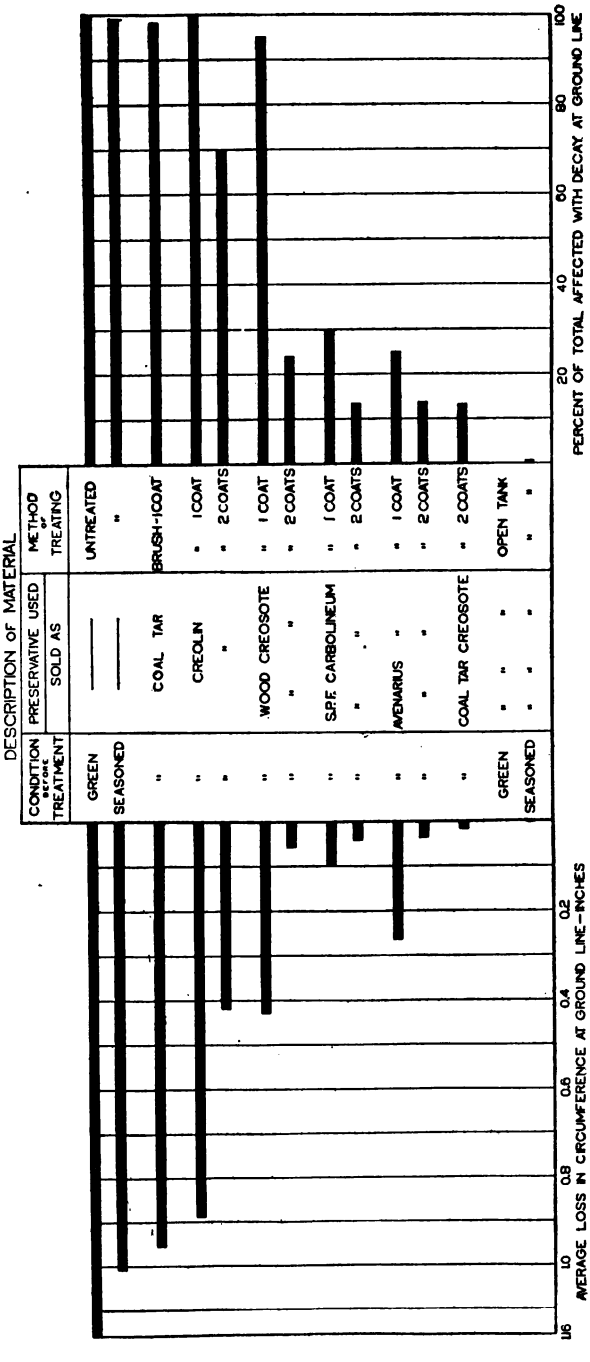

FIG. 1.—Condition of experimental poles in Warren-Buffalo line 5 years after placement.

however, were not influenced by the preservative. Decay in the treated zone rarely extended more than 6 inches above the ground line. Occasionally some was found in hollow knots above this point. Poles thus affected, however, are not included among those classed as showing decay. Insect damage to poles is discussed on page 13.[1]

EXPERIMENTAL POLES IN THE POUGHKEEPSIE-NEWTON SQUARE LINE.

The results from this experimental line are not as conclusive as those from the one just described. Only 72 poles were placed, and records showing the details of their preparation and treatment are not available. Table 4 gives the number of poles of each class and their average loss of circumference at the ground line. Figure 2 shows the same data in graphic form.

The poles were inspected in July, 1910, approximately eight years after placement.[2] In general the method of inspection was the same

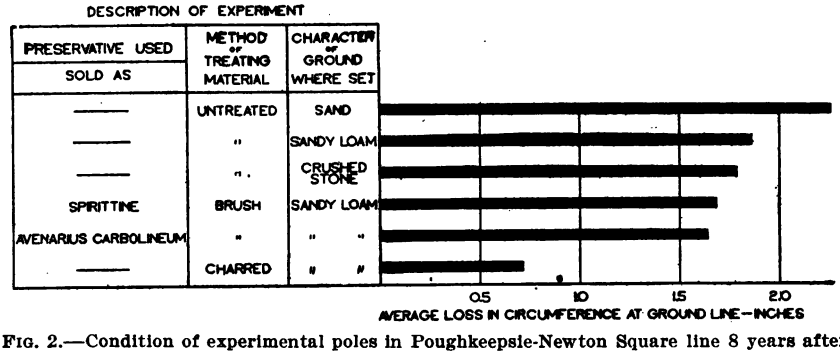

FIG. 2.—Condition of experimental poles in Poughkeepsie-Newton Square line 8 years after placement.

as that for the Warren-Buffalo line, except that the decayed portions near the ground line were first removed after which three circumference measurements were made, one 5 feet above the ground line, one 6 inches above, and one 6 inches below. To compute the average loss in circumference at the ground line the average taper per linear foot was obtained by dividing the difference between the circumference 5 feet above the ground line and that 6 inches above by 4.5, and the result added to the difference between the circumference 6 inches above the ground line and that 6 inches below.

[1] Notes on damage by insects to the poles in this and the Poughkeepsie-Newton Square line are given in Bureau of Entomology Bulletin 94, Part I, "Damage to Chestnut Telephone and Telegraph Poles by Wood-Boring Insects," by T. E. Snyder. Further information regarding damage to poles by insects is contained in Bureau of Entomology Circular 134, "Damage to Telephone and Telegraph Poles by Wood-Boring Insects," by the same author.

[2] The inspection was made by Messrs. R. F. Hosford, F. O. Mackey, A. W. May, and H. G. Spohr for the American Telephone & Telegraph Company, Mr. T. E. Snyder for the Bureau of Entomology, United States Department of Agriculture, and Mr. H. F. Weiss for the Forest Service.

TABLE 4.—*Description of poles set in the Poughkeepsie-Newton Square line and their average loss in circumference at ground line after eight years' service.*

Total number of poles.	Preservative used, sold as—	Method of treating.	Character of ground in which set.	Average loss in circumference at ground line.
				Inches.
10		Untreated	Sand	2.27
28		do	Sandy loam	1.87
8		do	Crushed stone	1.77
11	Spirittine	Brush	Sandy loam	1.68
10	Avenarius carbolineum	do	do	1.63
5		Charred	do	0.71

SUMMARY OF RESULTS OF INSPECTION OF EXPERIMENTAL POLES.

POLES IN WARREN-BUFFALO LINE.

(1) Both the green and seasoned poles butt-treated with coal-tar creosote by the open-tank process showed practically no decay at or near the ground line.

(2) The poles brush treated with two coats of coal-tar creosote, and preservatives sold as Avenarius carbolineum, S. P. F. carbolineum, and wood creosote, showed but little difference in the extent of decay. Their average loss of circumference was 0.02, 0.04, 0.04, and 0.06 inch, and the per cent affected with decay 14.5, 13.6, 13.4, and 24.0, respectively. The condition of these poles was next best to that of those treated with coal-tar creosote in the open tank.

(3) The poles brush treated, respectively, with one coat of preservatives sold as S. P. F. carbolineum and Avenarius carbolineum showed a much greater loss of circumference at the ground line than those treated with two coats of these preservatives. The average losses of circumference were 0.10 inch and 0.27 inch, and the per cent affected with decay 30 and 25, respectively.

(4) The poles brush treated with two coats of preservative sold as creolin and those similarly treated with one coat of preservative sold as wood creosote showed but slight difference in loss of circumference at the ground line, the average loss being 0.42 and 0.43 inch, and the per cent affected with decay 69.8 and 95.2, respectively.

(5) The poles brush treated, respectively, with one coat of preservatives sold as creolin and coal tar, showed a loss of circumference at the ground line of 0.89 and 0.95 inch, and a per cent affected with decay of 100 and 98, respectively. The loss with these poles was nearly as great as with the untreated.

(6) The untreated poles were practically all more or less affected with decay at the ground line, the average loss of circumference for those seasoned prior to placement being 1.01 inches, and for those placed green 1.16 inches. That two of those seasoned prior to place-

ment showed no decay at or near the ground line is possibly due to the fact that they were both set on a hillside or slope where the drainage was excellent. One of them was set in broken stone and rock.

(7) The reference in Bureau of Entomology Bulletin 94, Part I, pages 9–10, to insect damage to poles in this line is as follows:

> All these treatments, except the brush treatments with creolin and tar, were efficient in preventing the attacks of wood-boring insects, at least for a five-year period, in this northern climate. There was but little damage by insects to the poles in this test line. The most common injury to the untreated poles was by the large black carpenter ants which widen the longitudinal weathering checks, and hence induce more rapid decay. The work of the chestnut telephone-pole borer was found in several poles, and this beetle was evidently just beginning to attack these poles.

POLES IN POUGHKEEPSIE-NEWTON SQUARE LINE.

(1) The untreated poles set in crushed stone showed less decay at the ground line than similar poles set in sand, the average loss of circumference at that point being 1.77 inches and 2.27 inches, respectively.

(2) The poles with charred butts showed less decay at the ground line than similar uncharred and untreated poles set in either crushed stone or sand, their average loss in circumference at the ground being only 0.71 inch.

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HENRY S. GRAVES, Forester.

FOREST PRODUCTS LABORATORY SERIES.

QUANTITY AND QUALITY OF CREOSOTE FOUND IN TWO TREATED PILES AFTER LONG SERVICE.

BY

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FIG. 1. Fractional distillation curves, pile No. 1	6

QUANTITY AND QUALITY OF CREOSOTE FOUND IN TWO TREATED PILES AFTER LONG SERVICE.

INTRODUCTION.

This circular gives the results of analyses of the quantity and quality of creosote found in two treated piles[1] after long service. The piles were of pine (probably longleaf), and had been in the teredo-infested waters of the Gulf of Mexico for about 30 years. One was perfectly sound, but the other had been attacked, particularly at the water line. The analyses were made to determine whether the difference in their durability could be accounted for by a difference in the amount or character of creosote in the wood.

The piles had been treated by the old Bethell process, but no treating records are available, nor is it known where the creosote was obtained.

DESCRIPTION OF SPECIMENS.

Pile No. 1.—This pile, said to have been in service 30 years, was perfectly preserved, showing no indications of decay nor of attack by teredo. The portion above water was badly checked. It was received in three sections: Section 1, taken from above the water line; section 2, taken from near the mud line; section 3, taken from the lower end of the pile in the mud.

Pile No. 2.—This pile, which had been creosoted and placed in the Biloxi Bay trestle in 1879, and removed in July, 1910, had been attacked by teredo, especially near the water line. Only a portion of the whole pole, approximately 6 feet long, extending 3 feet above and 3 feet below the water line, was received. This will be considered as three sections: Section 1, above the water line; section 2, at the water line; section 3, below the water line.

Plate I, figure 1, shows radial views of the three sections of pile No. 1. It brings out clearly the depth of penetration of the creosote. Plate I, figure 2, shows three cross sections of pile No. 2. The work of the teredo, it will be noted, is in the treated wood.

[1] Shipped to Forest Products Laboratory by Mr. J. B. Lindsey, superintendent, West Pascagoula Creosoting Works, Gautier, Miss., in July, 1910.

EXAMINATION FOR THE QUANTITY OF CREOSOTE PRESENT.

Samples from the several portions of the piles were taken by borings distributed over the entire cross section. A weighed portion of the average samples from each section thus obtained was treated with chloroform; and the loss in weight after treatment and drying was determined. The loss includes all the creosote, all the rosin, and all the moisture. The extracted material was then treated with a sodium carbonate solution, and the dissolved rosin was recovered by precipitating it with acid. Moisture determinations were made on separate portions of the original sample. Then the amount of rosin and moisture was subtracted from the total of creosote, rosin, and water. The result was calculated in pounds of creosote per cubic foot of wood. Measurements of the relative proportions of the treated and untreated area of each cross section were then made. From these measurements and the previous calculations estimates were made of the quantity of creosote in the treated portion only. The results obtained are given in Table 1.

TABLE 1.—*Quantity of creosote in two piles.*

Pile No.	Section No.	Amount of creosote found per cubic foot.	
		Entire cross section.	Treated portion only.
		Pounds.	*Pounds.*
1	1	2.6	4.5
1	2	10.7	15.3
1	3	12.0	17.1
2	1	10.4	17.0
2	2	5.8	16.5
2	3	11.5	17.9

In the case of pile No. 2 the amount of creosote in the entire cross section at the water line (sec. 2) is only about half of that in either of the other two sections; but when calculated for the treated portion only it is nearly the same. This difference is due to the loss of a great portion of the creosoted wood in this section, making the proportion of untreated to treated wood much higher than in the other two cases. The proportion of the treated area in the three sections of this pile as received at the laboratory was: Section 1, 61 per cent treated; section 2, 35 per cent treated; section 3, 64 per cent treated.

ANALYSIS OF EXTRACTED OILS.

To determine the quality of the creosote, the oil was extracted from a large volume of chips by chloroform. The resulting extract was then freed from rosin by the use of sodium carbonate, and from

FIG. 1.—RADIAL VIEWS OF THREE SECTIONS FROM PILE NO. 1.

[1, above water line; 2, in the water; 3, in the mud.]

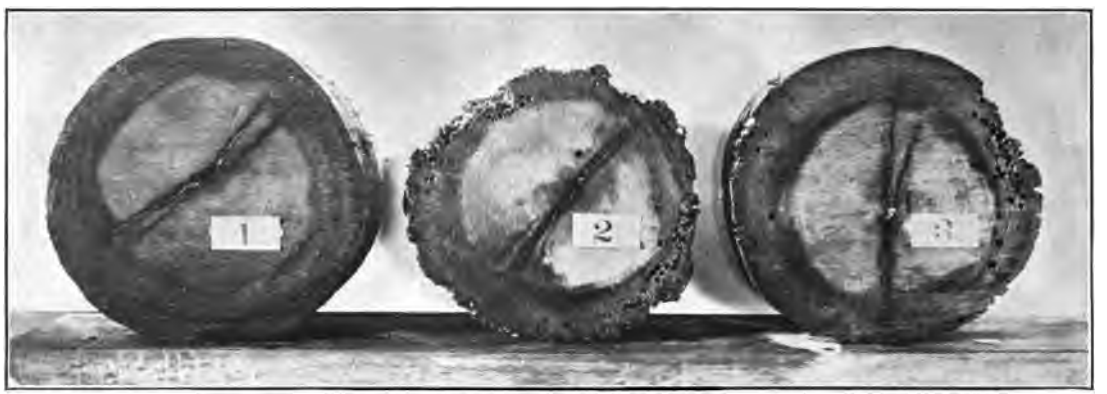

FIG. 2.—CROSS SECTIONS OF PILE NO. 2.

[1, above water line; 2, at water line; 3 below water.]

chloroform by distillation. The residual creosote was then analyzed according to the method described in Forest Service Circulars 112 and 191. The results of these analyses are given in Tables 2 and 3.

TABLE 2.—*Results of fractional distillation and index of refraction determinations of creosote extracted from pile No. 1.*

Temperature.	Percentage weight of distillate.			Average index of refraction of 2 and 3.
	Section 1.	Section 2.	Section 3.	
° C.				
205	2.0	.....	2.5	.....
215		2.7	2.0	.....
225		15.5	26.3	.....
235	8.2	12.0	8.5	1.5922
245		3.1	2.5	1.5920
255	13.7	2.1	2.0	1.5921
265		2.6	1.9	1.5939
275	6.6	2.4	2.5	1.5981
285	5.0	3.2	3.3	1.6041
295	6.2	4.1	3.5	1.6123
305	6.0	4.8	4.3	1.6203
320	10.5	8.6	7.9	1.6310
Residue.	41.6	38.4	32.3	.....

TABLE 3.—*Results of fractional distillation and index of refraction determinations of creosote extracted from pile No. 2.*

Temperature.	Percentage weight of distillate.			Average index of refraction of 2 and 3.
	Section 1.	Section 2.	Section 3.	
° C.				
235	4.0	4.6	6.0	1.5795
245	1.8		3.4	1.5825
255	1.6		3.2	1.5842
265	2.1	.....	8.9	1.5872
275	2.1			
285	3.0	4.2	9.2	1.5945
295	2.4	2.2	3.1	1.5997
305	1.0	2.6	.....	.....
Residue.	81.2	85.8	64.4	.....

None of the sections contained an appreciable amount of light oils. The creosote from section 3 of pile No. 1, in which presumably less change in the character of the oil had occurred, contained 2.5 per cent of oils distilling below 205°. The same creosote contained over 40 per cent of naphthalene oils (distilling between 205° and 255° C.). The other two sections of the same pile also contained considerable quantities of naphthalene.

The distillation of the creosote from pile No. 2 gave a very small percentage of distillate (below 305° C.) and a large amount of residue. The oil from section 3 (below the water line) of this pile, which yielded the largest amount of distillate, contained only 12.6 per cent of oils volatile below 255° C., and little or no naphthalene.

Sulphonation tests carried out on the fraction from 285° to 305° C. and 305° to 320° C. of the creosote from pile No. 1 failed to give any sulphonation residue. This oil resembles an imported creosote oil and is probably a pure coal-tar product. The index of refraction

values of the fractions above 295° C. are a little low, but this could easily be due to the presence of a small amount of rosin which had escaped separation before the oil was analyzed. The color, odor, and character of the fraction were like those of coal-tar creosote.

Sulphonation tests on the portions 285° to 305° C. of the creosote from pile No. 2 yielded a sulphonation residue of 2.6 per cent. The

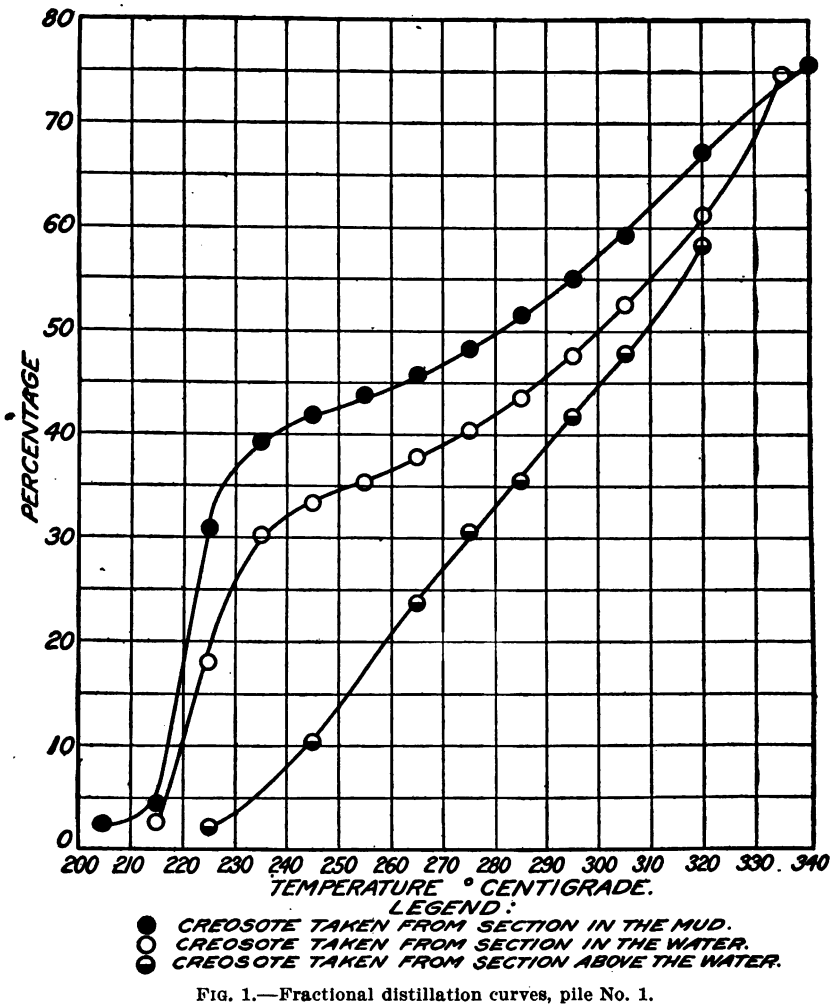

FIG. 1.—Fractional distillation curves, pile No. 1.

index of refraction values, as well as the color and odor, of this oil resemble those of water-gas-tar creosote.

CHANGE IN COMPOSITION OF THE CREOSOTE BY EXPOSURE.

Inspection of Table 2 indicates that whatever loss of creosote occurred in the several sections through leaching and volatilization while the piles were in use must have occurred in the lighter frac-

tions. If we assume that no change has occurred in the creosote extracted from section 3 of pile No. 1 (the portion buried in the mud) and that no change has occurred in the higher boiling fractions of the oil from the other two sections of this pile, the loss of oil in sections 1 and 2 may be computed as follows:

The fractions above 275° C. and residue for section 3 amounts to 51.3 per cent of the total; the same portion of the creosote extracted from section 2 amounts to 59.1 per cent. If the oil from section 3 is unchanged, as assumed above, the original volume of the oil in section 2 can readily be obtained by the proportion $59.1:x=51.3:100$, or $x=115$ per cent. That is, the creosote extracted from section 2 is the residual of an oil that was originally 15 per cent greater in volume. By a similar computation it is found that the creosote extracted from section 1 is the residual of a creosote originally 35 per cent greater in volume.

The change in composition of the creosote from sections 1 and 2 is shown more fully in Table 4, in which the fractional distillation is computed on the basis of percentage of what is assumed to be the original oil.

TABLE 4.—*Fractional distillation of creosote extracted from pile No. 1; in percentage of assumed original oil.*

Temperature.	Percentage weight of distillate.		
	Section 3.	Section 2.	Section 1.
°C.			
225	30.8	15.8	1.5
245	11.0	13.1	6.1
275	6.4	6.2	15.0
320	19.0	18.0	20.5
Residue.	32.3	33.4	30.8

Table 4 shows that the loss of creosote in that portion of the pile in the water as compared with the loss from the portion buried in the mud was confined to the fraction distilling below 225° C. and that the loss from the portion in the air occurred only in the fractions below 245° C. The small excess of distillate between 225° and 245° C. in the creosote from section 2 over that for the same fraction from section 3 may be accounted for by the effect which the absence of some of the lower boiling constituents at the lower stages of the distillation produce upon the fractionation of the distillate. The same explanation will account for part of the relatively large excess in the distillate between 245° and 275° C. of the oil from section 3.

Allowing for the losses as computed above, sections 1 and 2 of this pile originally had 6.1 and 17.6 pounds, respectively, of creosote per cubic foot of the treated portions. Section 2 thus agrees very well with section 3 (see Table 1). But the figure for section 1 is so much

at variance with the figures for sections 2 and 3 that this section probably lost creosote in such a manner as to leave the composition of the residual oil unchanged, as by "bleeding." The original volume of oil must therefore have been more than 35 per cent greater than the present.

Similar changes occurred in pile No. 2, except that in this case section 2, which is the portion at the water line, changed most. This may be due to its position, where it was subject to the influences both of sun and water; and also to the fact that, being riddled by the teredo, more opportunity was afforded for leaching of the creosote.

SUMMARY.

Practically no light oils (oils distilling below 205° C.) were found in the piles after their long period of service. If originally present, they were lost by volatilization and leaching.

The creosote in the pile which was perfectly preserved contained originally at least 40 per cent of naphthalene fractions, a large portion of which remained in the wood. The creosote in the pile, which was less perfectly preserved, contained little or no naphthalene.

The pitchy matter, which on distillation formed the residue above 320° C. (pile No. 2), is seemingly of an inert character and little objectionable to the teredo. A heavy treatment with creosote consisting largely of this material did not entirely save the pile from attack.

Loss of oil from that portion of the pile in the water, in the case of the creosote in pile No. 1, which is a pure coal-tar creosote, apparently occurred only in the fraction distilling below 225° C.

Approved:

JAMES WILSON,
Secretary of Agriculture.

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Issued September 14, 1912.

U. S. DEPARTMENT OF AGRICULTURE,

FOREST SERVICE—Circular 200.

HENRY S. GRAVES, Forester.

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FOREST PRODUCTS LABORATORY SERIES.

THE ABSORPTION OF CREOSOTE BY THE CELL WALLS OF WOOD.

BY

CLYDE H. TEESDALE,

Assistant Engineer in Forest Products.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1912.

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THE ABSORPTION OF CREOSOTE BY THE CELL WALLS OF WOOD.

EFFECT OF ABSORPTION BY CELL WALLS.

The location of the creosote absorbed by wood in preservative treatment has much to do with the mechanical properties of the treated material. If the cell walls do not absorb creosote, wood properly treated should not suffer a decrease in strength, provided no chemical reaction takes place. If, on the other hand, the cell walls do absorb creosote, then a weakening effect, similar to that produced by moisture in the wood, may be expected.

PAST AND PRESENT INVESTIGATIONS.

Microscopic examinations of creosoted wood made by the Forest Service in the past led to the belief that creosote did not enter the cell walls. Later experiments, however, apparently showed this supposition to be incorrect. Creosote oil, seen in a mass, appears of a dark or almost black color, but in a thin layer is transparent and almost colorless. Failure to see it in a section of wood mounted for microscopical examination, therefore, is no proof of its absence, and evidence must be sought for by other methods.

It is well known that the volume of wood varies with the amount of moisture present, increasing with the absorption of water by the cell walls, and shrinking with drying.[1] It is therefore reasonable to suppose that if creosote is absorbed by the cell walls an effect analogous to that produced by the absorption of water will occur.

Measurements[2] made at the Yale Forest School Laboratory on test specimens before and after soaking in creosote (Table 1, p. 6) indicated a slight but unmistakable swelling in the specimens thus treated. The results of another series having a similar purpose, but differing materially in the methods employed, made recently at the Forest Products Laboratory, are given in this circular.

[1] It is the water absorbed by the cell walls which causes swelling, not the free water in the cells, since after the fiber saturation point is reached water is still absorbed as free water, but no further swelling occurs. See Forest Service Circular 108, pages 8, 13 and 14.

[2] By Harry D. Tiemann, of the Forest Service.

METHODS OF TEST.

In these tests a number of pieces approximately 2 by $\frac{3}{4}$ by $\frac{1}{8}$ inch were prepared from yew (*Taxus*) and eastern hemlock (*Tsuga canadensis*). The pieces were dried in an oven at 212° F. for 24 hours, then placed in a desiccator and weighed when cold to the nearest 0.001 gram, after which they were coated with paraffin and again weighed in air and also under water.

The weight of each piece under water was corrected by subtracting the weight (under water) of the paraffin on the piece.[1] The volume of each piece was found by subtracting its weight under water (corrected) from its weight in air, the weight of the water displaced, in grams, being numerically equal to the volume in cubic centimeters.

The pieces were treated with creosote for $1\frac{1}{2}$ hours at 180° F. and 150 pounds pressure per square inch. The creosote was then heated to 220° F., and the pieces allowed to remain in it at this temperature for 5 hours, after which they were cooled in the oil. The amount of water in the creosote was not determined, but was probably less than 0.5 per cent.

When the oil had reached room temperature (about 75° F.) the pieces were removed, the surplus oil on the surface was carefully wiped off, and the pieces were again weighed in air and in water and their volumes determined as described before. The paraffin applied to the pieces before treatment was dissolved during the treatment. It was not necessary to coat the treated pieces with paraffin because the creosote made them sufficiently waterproof.

TREATMENTS WITH CREOSOTE FREE FROM WATER.

Since there was a trace of water in the creosote used, a second test was made with creosote from which the water had been removed. About 1 liter of creosote containing 0.2 per cent water was allowed to stand over 1 pound of fused calcium chloride for 24 hours. Both the creosote and calcium chloride were well shaken at intervals. At the end of this period the oil was filtered.

In this test hard maple, dried for 24 hours at 102° C., was used. The pieces, of approximately the same size as those used in the previous test, were placed in an 8-ounce bottle, *B* (fig. 1), the bottle and also the tube, *C*, being filled with the water-free creosote. A second 4-ounce bottle, *A*, was filled to a depth of one-half inch with

[1] The weight of the paraffin was determined as follows: Let P = weight in air of paraffin on piece (in grams), and p = weight under water of paraffin on piece (in grams). Then $p = P$ − weight of water displaced. Also specific gravity $= \frac{P}{\text{weight of water displaced}} = 0.89$. Or, weight of water displaced $= \frac{P}{0.89}$. Hence, $p = P - \frac{P}{0.89} = P - 1.12P = -0.12P$.

mercury, and the remaining space with water-free creosote. The glass tube, *C*, connecting the two bottles, dipped one-fourth inch beneath the surface of the mercury in the 4-ounce bottle. A second open glass tube, *D*, led from the 4-ounce bottle to the outside.

This apparatus was placed in the treating cylinder, and a pressure of 250 pounds at a temperature of from 150° F. to 200° F. was applied for 1 hour. A gradually rising temperature was maintained throughout the treatment in order to guard against outside oil being drawn into the apparatus. The mercury seal was provided as an additional precaution against anything but mercury being drawn into the 8-ounce bottle *B*. With this apparatus, the outside pressure medium might have been creosote or any other liquid, but the pieces could have been treated only with the creosote which had been placed in the bottle.

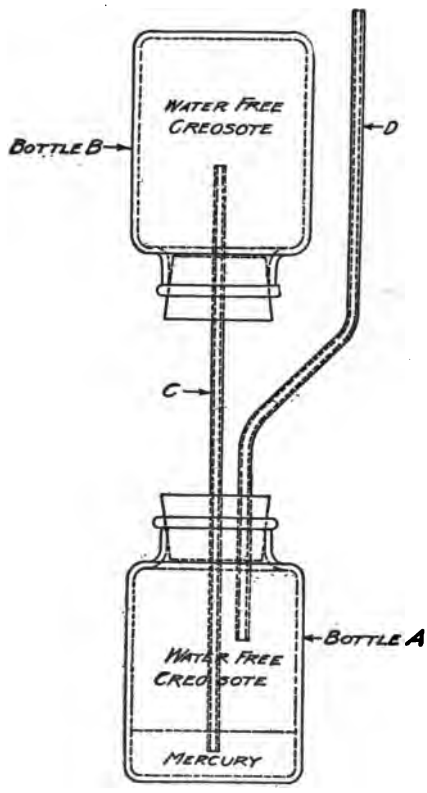

FIG. 1.—Arrangement of apparatus for treating test pieces with water-free creosote.

The volumes of the hard-maple pieces before and after treatment with the water-free creosote were determined as described for yew and hemlock.

RESULTS OF TESTS.

Table 1 gives the measurements made at the Yale Laboratory on one specimen each of spruce, chestnut, longleaf pine, loblolly pine, and white oak. Table 2 gives results of the tests on yew and hemlock, and Table 3 of those on hard maple.

The average increases in volume resulting from the treatments of the three species in per cent of the volumes before treatment were:

	Per cent.
Yew, heartwood	6.81
Yew, sapwood	10.70
Hemlock, heartwood	7.30
Hard maple, heartwood	8.14

It is thus seen that a decided swelling takes place in wood impregnated with creosote. This swelling, the tests indicate, is caused by the absorption of the creosote by the cell walls

TABLE 1.—*Swelling of wood due to absorption of creosote.*[1]

Measurements.	Species.				
	Spruce.	Chestnut.	Longleaf pine.	Loblolly pine.	White oak.
Dec. 5, 1908:					
Weight.....grams..	7.400	8.240	9.290	7.010	9.540
Radial dimension.....inches..	1.989	1.976	1.973	1.985	1.967
Tangential dimension.....do...	1.965	1.952	1.470	1.479	1.466
Dec. 7, 1908:					
Weight.....grams..	12.500	12.650	10.550	11.500	10.680
Radial dimension.....inches..	1.989	1.979	1.975	1.988	1.968
Swelling.....per cent..	0	.150	.100	.150	.050
Tangential dimension.....inches..	1.968	1.956	1.473	1.481	1.467
Swelling.....per cent..	.150	.200	.200	.140	.070
Dec. 14, 1908:					
Weight.....grams..	14.000	13.580	10.970	12.170	10.980
Radial dimension.....inches..	1.991	1.980	1.976	1.988	1.968
Swelling.....per cent..	.100	.200	.150	.150	.050
Tangential dimension.....inches..	1.968	1.956	1.473	1.481	1.469
Swelling.....per cent..	.150	.200	.200	.140	.200
Apr. 10, 1909:					
Weight.....grams..	18.800	17.400	13.900	15.200	12.750
Radial dimension.....inches..	1.993	1.991	1.995	2.002	1.995
Swelling.....per cent..	.200	.760	1.110	.860	1.420
Tangential dimension.....inches..	2.004	1.989	1.491	1.496	1.501
Swelling.....per cent..	1.980	1.900	1.430	1.160	2.390
Sept. 9, 1909:					
Weight.....grams..	18.850	17.500	14.050	15.200	13.100
Radial dimension.....inches..	2.007	1.993	2.001	2.003	1.999
Swelling.....per cent..	.900	.860	1.420	.910	1.630
Tangential dimension.....inches..	2.000	1.992	1.496	1.499	1.507
Swelling.....per cent..	1.780	2.050	1.770	1.350	2.800
Sept. 10, 1909 (after heating 100° C. five hours and cooling in vacuum):					
Weight.....grams..	19.100	17.700	14.150	15.300	13.300
Radial dimension.....inches..	2.008	1.997	2.006	2.006	2.011
Swelling.....per cent..	.950	1.060	1.670	1.060	2.240
Tangential dimension.....inches..	2.002	2.000	1.501	1.503	1.526
Swelling.....per cent..	1.880	2.460	2.110	1.620	4.100

[1] The disks measured were cut from thoroughly air-dry wood (used in preference to oven-dry wood to avoid any possible subsequent absorption of moisture from the air) and were placed in a quart preserving jar containing creosote and sealed so that no additional dampness could enter. The creosote had previously been dried, and only partially filled the jar. The disks were 0.126 inch thick when placed in the jar Dec. 5, 1908. They were kept at about 17° C. until finally heated to 100° C. for about 5 hours with the cover of the jar loose, then cooled under seal so as to be in partial vacuum.

TABLE 2.—*Weights and volumes of yew and hemlock test pieces before and after treatment.*

Species.	No.	Oven-dry weight of piece.	Weight of paraffin.	Corrected weight of piece in water.	Weight after treatment.	Absorption of creosote.	Weight in water after treatment.	Volume before treatment.	Volume after treatment.	Increase in volume.	Increase in volume.
		Grams.	*Gram.*	*Grams.*	*Grams.*	*Gram per c. c.*[1]	*Gram.*	*c. c.*	*c. c.*	*c. c.*	*Per ct.*
Yew, heart[2]	1	2.288	0.034	−1.573	5.087	0.725	0.812	3.861	4.102	0.241	6.24
	2	2.047	.055	−1.385	4.562	.733	.705	3.432	3.644	.212	6.18
	3	1.808	.044	−1.289	3.845	.657	.359	3.097	3.308	.211	6.82
	4	2.147	.064	−1.483	4.840	.742	.747	3.630	3.862	.232	6.30
	6	1.666	.108	−1.041	3.645	.732	.548	2.707	2.899	.192	7.11
	7	2.179	.084	−1.319	4.682	.715	.751	3.499	3.732	.233	6.67
	8	1.728	.101	−1.044	3.822	.755	.580	2.773	3.004	.231	8.33
Average											6.81
Yew, sap	9	.967	.063	− .749	2.405	.837	.307	1.717	1.913	.196	11.4
	10	1.140	.113	− .775	2.720	.825	.385	1.915	2.107	.192	10.0
Average											10.7
Hemlock, heart	11	1.158	.109	−1.036	2.844	.769	.273	2.194	2.357	.163	7.44
	12	1.330	.092	−1.487	3.616	.812	.344	2.817	3.009	.192	6.75
	13	1.481	.104	−1.419	3.750	.782	.302	2.901	3.130	.229	7.90
	14	1.373	.112	−1.849	4.102	.847	.284	3.223	3.452	.229	7.12
Average											7.30

[1] Based on volume of wood before treatment.

[2] Piece No. 5 was lost during the tests.

TABLE 3.—*Weights and volumes of maple test pieces before and after treatment.*

Species.	No.	Oven-dry weight of piece.	Weight of paraffin.	Corrected weight of piece in water.	Weight after treatment.	Absorption of creosote.	Weight in water after treatment.	Volume before treatment.	Volume after treatment.	Increase in volume.	Increase in volume.
		Grams.	*Gram.*	*Grams.*	*Grams.*	*Gram per c. c.*[1]	*Gram.*	*c. c.*	*c. c.*	*c. c.*	*Per ct.*
Maple, heart	1	2.434	0.127	−1.112	4.095	0.456	0.148	3.646	3.947	0.301	8.26
	2	2.470	.160	−1.160	4.307	.506	.370	3.630	3.937	.307	8.46
	3	2.050	.143	− .982	3.608	.514	.291	3.032	3.317	.285	9.45
	4	2.145	.140	−1.009	3.755	.510	.338	3.154	3.417	.263	8.34
	5	2.044	.130	−1.024	3.588	.503	.279	3.068	3.309	.241	7.86
	6	2.141	.102	−1.102	3.800	.512	.324	3.243	3.476	.233	7.18
	7	2.381	.107	−1.164	4.168	.504	.336	3.545	3.832	.287	8.10
	8	2.310	.135	−1.138	4.057	.507	.350	3.448	3.707	.259	7.50
Average											8.14

[1] Based on volume of wood before treatment.

Approved:

JAMES WILSON,
Secretary of Agriculture.

WASHINGTON, D. C., *February 3, 1912.*

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U. S. DEPARTMENT OF AGRICULTURE,

FOREST SERVICE—Circular 201.

HENRY S. GRAVES, Forester.

EMORY OAK IN SOUTHERN ARIZONA.

By

FRANK J. PHILLIPS,

Collaborator.

34820°—12

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EMORY OAK IN SOUTHERN ARIZONA.

Emory oak (*Quercus emoryi*) forms one of the most important types of the open woodland forest of the Southwest, and is the most common oak in the mountains of southern New Mexico and Arizona. It affords protection to watersheds, and has high value for fuel in a region where wood is scarce. Also, there is a possibility that its bark, which is fairly rich in tannin, may become a source of tannic acid for the Southwest.

RANGE AND OCCURRENCE.

The east and west range of Emory oak is from western Texas to the western slopes of the Pajarito Mountains, Ariz.; from north to south it occurs from the south-central portion of Arizona (south of the Colorado Plateau) to the south-central part of the Province of Chihuahua, Mexico. In Texas it grows on most of the mountain ranges west of the Pecos River, and is especially abundant in the canyons and on the southern slopes of the Limpio and Chisos Mountains. Its best development in the United States is probably in the Garces National Forest, in southern Arizona, where it furnishes at least half of the timber supply. Here it is valued for fuel more than any other native oak.

CLIMATE.

The climate typical of the region within which Emory oak grows is that of the mountains along the Mexican border, where the two rainy seasons are from November to March, inclusive, and from July to September. At the base of the foothills the average annual precipitation is approximately from 11 to 12 inches; but in the mountains it may be as much as 25 inches for a series of years, or even more in exceptional years.

The winter rains, which are very irregular, originate on the Pacific coast, and are usually preceded by easterly winds. They are not as torrential as the summer rains, which originate in the Tropics. From these the precipitation comes mainly during the afternoon or evening in the form of heavy local thunderstorms, which occur

daily for periods of a week or more at a time, starting usually about the end of the first week in July. While these storms furnish most of the soil water for tree growth, the evaporation, at low altitudes, is much greater than the precipitation.

In the whole region there is but little tree growth in the winter rainy season, only moderate growth in the spring dry season, much growth in the summer rainy season, and slight growth in the late dry season.

SOIL AND MOISTURE.

Emory oak so adapts itself to conditions of soil and moisture that it is able to grow on a variety of sites, though it does best in deep alluvial soils with abundant water. In the best sites in the broad valleys the soil may be 20 feet deep and have a constant supply of underground water within reach of the roots. In the narrow valleys and on the slope bases and bench lands the soil may vary, on the best sites, from 3 to 15 feet in depth, with moderately good soil-moisture conditions, and, in the best situations, some periodic surface flow of water. On the slopes the site has a very decided influence on growth, and there is marked advantage to the trees in the deeper soils of the lower slopes and in the greater moisture of north and east slopes.

ASSOCIATED SPECIES.

In broad, open valleys the commonest associates of Emory oak are mesquite (*Prosopis juliflora velutina*), acacia (*Acacia greggii*), and desert willow (*Chilopsis linearis*), though on the most moist situations there will be ash (*Fraxinus velutina*), sycamore (*Platanus wrightii*), and willow (*Salix taxifolia*). Although scarcely ever found in the bottoms of the valleys, blue oak (*Quercus oblongifolia*) is an intimate associate on the bases of the slopes that border these valleys.

In the narrow valleys, on slope bases, and on benches the stand may be pure or mixed with any one or all of the following species: Arizona white oak (*Quercus arizonica*), white-leaf oak (*Quercus hypoleuca*), Chihuahua pine (*Pinus chihuahuana*), and alligator juniper (*Juniperus pachyphlœa*). Even when all are present Emory oak usually predominates.

Since slope stands are transitional, they present the greatest diversity of associated species. Arizona white oak and white-leaved oak are the commonest associates on north and east slopes; on south and west slopes, blue oak, mountain mahogany (*Cercocarpus parvifolius*), cliff rose, manzanita (*Arbutus xalapensis*), and numerous shrubs. At elevations of from 6,000 to 7,000 feet there is a considerable mixture of Mexican piñon (*Pinus cembroides*).

FIG. 1.—TYPICAL STAND OF VETERAN EMORY OAK IN THE BROAD, OPEN VALLEYS; ALAMO CANYON, ELEVATION 3,500 TO 4,500 FEET.

FIG. 2.—THICKET STAND OF EMORY OAK IN WHICH SIDE BRANCHES HAVE BEEN PRUNED TO A HEIGHT OF 5 FEET; NEAR MOWRY MINE, PATAGONIA MOUNTAINS.

FIG. 1.—NEARLY PURE THICKET STAND OF EMORY OAK TRANSITIONAL BETWEEN BROAD VALLEY AND BENCH TYPE, WITH GOOD SLOPE STAND IN BACKGROUND; SOUTHWEST OF MOWRY MINE, PATAGONIA MOUNTAINS.

FIG. 2.—MIXED STAND OF EMORY OAK AND WHITE-LEAVED OAK ON A NORTH SLOPE; NEAR FLUX CANYON, PATAGONIA MOUNTAINS.

CHARACTERISTICS OF THE TREE.

FORM.

Emory oak varies in form and size and character of stand more than any other oaks in its range, according to its situation; its leaf and bark forms, however, are fairly constant. This silvical variation is very pronounced in the extreme forms, although the gradation between types may be very slight. In a general way there are characteristic bottom stands and slope stands, as exemplified in the Garces National Forest, and these may be subdivided according to location. For the bottom stands there are: (1) Those of the broad open valleys at elevations of from 3,500 to 4,500 feet; (2) those in narrower valleys at from 4,500 to 5,500 feet; and (3) those on slope bases and bench lands at elevations of from 3,800 to 5,500 feet. There are two subdivisions of the slope stands: (1) Those on north and east slopes at elevations of from 5,000 to 7,000 feet and (2) those on south and west slopes at from 5,000 to 7,000 feet.

In the broad, open valleys the tree reaches its maximum development, with breast-high diameters of from 2 to 3 feet and a total height of from 60 to 70 feet. Indeed, some of the trees in these situations are 3½ or 4 feet in diameter and 80 feet tall.[1] In these large trees the clear length may be from 10 to 30 feet. The shape of the crown varies according to the age of the tree, being a tall and regular oblong in the younger veterans and a broad, flat oval in the old ones. One strong characteristic is the flat plane in which the leaves and twigs grow on the branches. This peculiar growth is not particularly noticeable in standing trees, but shows very plainly in one that has been felled.

In the narrow valleys the trees are much smaller, with a breast-high diameter of from 6 to 8 inches and a height of 20 or 30 feet, though occasionally they may be from 12 to 18 inches in diameter and as much as 40 feet high. Here the clear length varies from 1 to 15 feet, and the crown is a narrow oblong, with a tendency, however, toward the oval in the older trees. Not only do the leaves and twigs grow in horizontal planes, even more markedly than in the trees of the broad valleys, but the branches themselves are nearly at right angles with the stem.

In the slope stands the individual trees are shorter and have a wider crown in proportion to their height. The stands on the north and east slopes are from two to three times as dense as those on south and west slopes.

[1] Dr. Edgar Alexander Mearns states, in Bulletin 56, U. S. National Museum, "Mammals of the Mexican Boundary of the United States," that he has seen trees in the neighborhood of the Garces National Forest which are about 100 feet high.

FOLIAGE.

Although usually considered an evergreen, like the live oaks, there may be times during the year when Emory oak is leafless. Old trees are rarely without some leaves, but younger ones, up to 15 or 20 feet tall, may be bare for two or three weeks before the new leaves appear, and, in dry seasons, even for a month or two. During normal seasons Emory oak leafs in late April or early May, but, in an abnormally dry year, may not leaf until June or early July. There is a current opinion that all the old leaves are shed just before the new crop appears; as a matter of fact trees begin to shed their leaves in the fall, and continue to do so throughout the winter and early spring.

ROOT SYSTEM.

Just as the form of the tree above ground is determined largely by the site, so is the root system. The best developed roots are on the large trees of the broad valleys, where the soil is deep, porous, and moderately moist. They have well-developed tap roots and numerous laterals within the first 2 feet beneath the surface. The laterals, like the branches above, spread out in distinct planes, and at varying distances from the stem, have sublaterals that go down at right angles from 3 to 10 feet. The laterals that are close to the surface serve two purposes: First, they secure proper aeration when the ground is saturated; and, second, they are needed to anchor such large-crowned trees. The tree has an overdeveloped, or hypertrophied, root collar, because the present survivors are not of seedling growth. Even with trees of undoubted seedling origin, repeated killing back, either by fire, browsing animals, or frost and drought, make the final trunk the survivor of many sprouts or sets of sprouts.

Other marked characteristics of the root system are the intense red color of the inner bark, the small proportion of root branching, except near the root tips, and the strong development of mycorrhiza.

GROWTH.

It is comparatively easy to determine the growth of Emory oak, because its annual rings are more distinct than those of other black oaks of the region and much plainer than those of the white oaks. Generally there is an abrupt formation of the large thick-walled vessels in spring, though on poor sites, or as the result of abnormal seasons, the annual character of the rings may not be readily determined. Sometimes, as in seasons of more than one distinct growth period, with a time of comparative vegetative rest between, there will be false rings, though these are rare.

Even on the same site growth may vary with individual trees or groups of trees, and slightly better soil-moisture conditions in iso-

lated patches will enable some trees to put on their leaves in a dry season during late April or early May, while most of the trees are leafless until June or July. This may result in a broad ring on the favored trees, while the rest of the stand can make only a narrow one.

A peculiar growth characterized thousands of acres in the Canelo Hills, where an inch of rain in early June was not followed by any precipitation for a month. Emory oak and Arizona white oak developed leaves, which were not more than from 1 to 2 cm. (0.4 to 0.8 inch) long. When the unusual rainy season started in July the June leaves failed to develop further, which indicated that the meristem tissue had lost its function, though the leaves seemed normal in all other respects. New leaves of normal size were formed, and these, at the end of the growing season, were from 10 to 20 times as large as the leaves formed in June. Still another indication of the adaptability of the species to changes in growth conditions is the appearance of new leaves and shoots as late as the first of September.

Sprouts in the valley stands were measured for height and diameter growth, and the results of these measurements are given in Table 1. "Injury sprouts" are those which are the results of accidental harm, such as would come through grazing or fire. The stump sprouts are, of course, those which spring from the stump of a felled tree.

TABLE 1.—*Height and diameter growth of sprouts in valley stands.*

Age.	Height.		Diameter, breast high.	
	Injury sprouts.	Stump sprouts.	Injury sprouts.	Stump sprouts.
Years.	*Feet.*	*Feet.*	*Inches.*	*Inches.*
5	4.5	8.3	0.85	1.20
10	8.7	14.5	1.70	2.95
15	12.4	17.8	2.60	4.65
20	15.7	20.1	3.50	6.15
25	18.7	22.1	4.55	7.45
30	21.3	23.8	5.65	8.65
35	23.5	[1] 25.4	6.80	[1] 9.85
40	25.5	.....	7.90	.....
45	27.5	.....	9.05	.....
50	29.2	.....	10.20	.....
55	30.7	.....	11.25	.....
60	32.2	.....	12.30	.....
65	33.5	.....	13.30	.....
70	34.7	.....	14.30	.....
75	35.9	.....	15.30	.....
80	37.1	.....	16.20	.....
85	38.2	.....	17.10	.....
90	39.3	.....	17.95	.....
95	40.3	.....	18.80	.....
100	41.9	.....	19.60	.....
105	42.4	.....	20.35	.....
110	43.4	.....	21.15	.....
115	44.4	.....	21.85	.....
120	45.3	.....	22.60	.....
125	46.3	.....	23.30	.....
130	47.3	.....	24.00	.....
135	48.3	.....	24.75	.....
140	49.3	.....	25.50	.....
145	50.3	.....	26.30	.....
150	51.3	.....	.....	.....

[1] No stumps were older than 35 years.

Table 1 shows that the height growth is slow and the diameter growth fairly rapid, and that, at the start, the growth of stump sprouts is better than that of injury sprouts. Yet, at 35 years, the rate of height growth of the injury sprouts is 2.2 feet in 5 years as against only 1.6 feet for those from the stump; and the rate of diameter growth of injury sprouts for the same period is 1.15 inches and only 1 inch for the stump sprouts. This difference is probably attributable to the fact that the injury stools are younger, and therefore more vigorous. At the same time it must be understood that the larger number of sprouts from a stump will more than compensate in actual volume of wood production for a greater growth of the individual injury sprouts. Moreover, the stump sprouts tend to have a greater clear length than the injury sprouts.

In order to secure an exact idea of the effect of elevation on growth measurements were taken at intervals of 100 feet on a northeast slope, the summit of which was 350 feet above the valley, with an absolute elevation of 5,800 feet. That increase in elevation results in decreased growth is shown in Table 2. The differences in growth may be ascribed primarily to differences in soil depth, soil moisture, and protection from wind, all of these influences being more favorable at the bases of the slopes.

TABLE 2.—*Influence of elevation on height and diameter growth in slope stands.*

Altitude.	Average age.	Average height.	Average diameter, breast high.	Average yearly height growth.	Average yearly diameter growth.
Feet.	*Years.*	*Feet.*	*Inches.*	*Foot.*	*Inch.*
5,550	10.6	8.03	1.17	0.758	0.110
5,650	15.7	7.70	1.09	.427	.070
5,750	18.8	7.05	1.03	.375	.055

REPRODUCTION.

Although Emory oak produces seed abundantly, and much of this seed germinates to furnish the original seedlings from which subsequent sprouts develop, reproduction is due almost entirely to sprout growth. Coppice growth is evident everywhere, but even where this is only one straight stem, as in the broad valleys, careful examination will reveal its sprout origin. In fact, diligent search for a distinctly seedling growth failed to disclose a single example. While more actual seedling reproduction would ensue if fires and grazing did not kill back the growth, another reason for the comparative lack of seedling growth is the destruction of the acorns themselves. These usually ripen in August and are a staple article of food with the Indians and Mexicans, who collect them in immense quantities, gathering them from the ground. In a good year one man can pick up 50 pounds of acorns in a day, and they sell for not less than 5

CHARACTERISTIC ROOT COLLARS OF EMORY OAK.

LEAVES OF EMORY OAK AND ARIZONA WHITE OAK, SHOWING THE RELATIVE SIZE OF FOLIAGE PUT FORTH BEFORE AND AFTER A RAINY SEASON; COLLECTED IN THE CANELO HILLS DURING THE LAST WEEK OF SEPTEMBER.

cents a pound, even when the supply is plentiful. Birds, bears, and rodents eat the acorns, and many are spoiled by insect larvæ.

Since most of the stands have not been touched by the ax, the sprouts originate from injury to seedling growth, the principal sources of injury being fire, grazing, drought, or frost. These sprouts have been designated "injury sprouts," in contrast to the utilization or stump sprouts. Fire has been the chief source of injury, the fires having been set in the interest of the grazing industry, and rarely extinguished except where they threatened houses. Most of the stools represent many generations of sprouts, and none less than two generations. Since the damage from grazing and from unfavorable climatic conditions is restricted to seedlings or shoots, fire and cutting account for the origin of most of the stands.

Trees have been cut only near towns and mining camps, and since the stumps persist for at least 35 years, the resulting sprouts clearly show their origin. Stump sprouts, like injury sprouts, spring from the root collar, with but few exceptions. In the valleys only from 1 to 6 per cent of the stump sprouts come from the stem, and in all cases these were fewer in number and weaker in growth than those from the root collar. The reason for this lack of sprouting above the roots is found in the dryness of the climate and the consequent shrinking of the wood away from the bark, so that there is but slight chance for the formation of a callus. In the narrow valleys at higher elevations there was a slightly greater proportion of stem sprouts—from 2 to 10 per cent—due largely to lower stump heights, smaller diameter, and better atmospheric conditions. But even in stumps cut close to the ground most of the growth comes from dormant buds at the root collar.

Careful counts showed that there is little if any difference in the sprouting capacity between the north and south sides of the stumps, and the shade of the stump evidently has no protective influence.

Small stumps are more likely to produce sprouts and sprouts of greater vigor than large stumps.

As with other broadleaf trees, the season of cutting has a decided influence on the sprouting capacity of the resultant stump, and summer cutting is most likely to result in the death of the stump. When land is to be cleared for cultivation the trees are cut in August or are girdled then and cut the following year. Emory oak is locally considered a tree which it is hard to kill simply by cutting. Nevertheless, on many cut-over slopes in the Pajarito Mountains the sprout growth has failed entirely on areas immediately adjoining thrifty stands of stump coppice. It appears, therefore, that the season, or possibly the method of cutting, or the occurrence of a severe drought have caused the failure. It seems reasonable that the best time for cutting to secure coppice growth is between November and April.

CAUSES OF INJURY.

FIRE.

Emory oak constitutes no exception to the general truism about any tree in America—that fire is its greatest enemy. Fire is not only a source of injury in itself but is the antecedent of secondary injury by insects or fungi, or both combined. The worst fire season lasts from February until the heavy rains of July, and the most severe fires occur in May or June.

In the open valleys the thick bark of the old trees forms a sufficient protection against most of the fires, but younger trees, up to 2 or 3 inches in diameter at the base are seriously injured, and smaller sprouts and young shoots are killed outright. In narrow valleys and on bench lands, where the thickets reach a maximum density and there is likely to be a good deal of litter on the ground, the fires are extraordinarily bad, and may kill as much as 30 per cent of the dominant stand and all of the shoots and suppressed growth. Slope stands are damaged in direct proportion to their density and the amount of ground cover.

The usual fire damage on all growth more than 2 inches in diameter breast high—below that diameter the trees are killed—consists of a scorched bark which is rarely burned through, though it is usually cracked and loosened from the trunk. This permits the entrance of fungi which cause a heart rot that is very common.

When sprouts are killed back to the ground, from 5 to 25 new shoots spring from the root collar and make a height growth of from 1 to 4 feet the first season. If the fire is late in the season this growth fails to harden sufficiently to withstand winter conditions and is partially killed back. Occasionally some of the very tender shoots are affected by sun scald.

FIRE PREVENTION.

The people of the region have yet to learn the necessity of fire protection. Yet the effect of prevention of fire on the Garces National Forest can not fail to have an educative value, and the practice of allowing fires to run unchecked will come to an end. Fire fighting is comparatively easy because of the open nature of the stands, which makes most of the fires merely surface fires, except in the thickest stands or during severe winds. Where the grass is thick, the most effective method is judicious back-firing supplemented by beating the fires out with squares of canvas or wet gunny sacks; where the grass cover is thin or broken, the beating alone will suffice. The ground is not rough, it imposes no difficulties of transportation, and there are plenty of roads and trails, so that fire fighters can go readily from one place to another. The one difficulty is the scarcity of labor available, but this can be partly met by an adequate system of patrol supplemented by the use of the telephone.

INSECTS.

Observations indicate that the wood and bark boring insects do considerable damage. In certain stands as much as 95 per cent show the borings from the base to near the top of the tree. The openings in the boles and branches seem to give entrance to wood-decaying fungi.

WIND.

Windshake is prevalent, affecting one-eighth of the trees in even the most sheltered stands, and as much as three-fourths in the most exposed. Combined with the beetle galleries, the shake adds greatly to the liability to severe heart rot.

GRAZING.

In the spring, when the range grasses are not available, cattle and horses browse on Emory and other oaks, mesquite, acacia, and other woody growth. Where this growth is limited and there is much stock the young oak sprouts may suffer considerably, and some stools may be killed outright as the result of grazing, though such severe injury is uncommon. Indeed, browsing may have a beneficial effect as a form of pruning early in the dry season, and certainly the evergreen oaks are an important asset to the grazing industry in helping to carry the stock over to the rainy season.

FUNGI AND MISTLETOE.[1]

The heartwood of living trees of the Emory oak is attacked by a number of species of fungi. *Polyporus dryophilus* Berk. frequently causes a brown and white mottled rot, commonly known as the piped rot; next in frequency of occurrence is *Fomes everhartii* (Ellis and Gall.), which causes a whitish rot varying to brown on the outer edges; *Polyporus sulphureus* (Bull.) Fr. occurs occasionally, producing a brown, coarsely checked rot; *Polyporus obtusus* Berk. and *Hydnum erinaceus* Bull. cause whitish rots of less frequency.

The wood of dead trees and timbers of oaks of this species are attacked by a number of species of fungi, which as a rule attack first the sapwood and later may rot the heartwood. *Ganoderma cortissii* (Berk.) Murr. causes a whitish, stringy rot of the butts of dead trees and stumps; *Polyporus gilvus* (Schw.) Fr. is found attacking the sapwood of defective living trees, as well as that of dead trees and logs; *Polyporus adustus* (Willd.) Fr., *Polystictus versicolor* (L.) Fr., *Polystictus sanguineus* (Mey.) Fr., and *Stereum* spp. are also common causes of decay in dead oak trees and timbers of this species.

[1] Contributed by Dr. George G. Hedgcock, Office of Investigations in Forest Pathology, Bureau of Plant Industry.

The mistletoe (*Phoradendron flavescens* (Pursh.) Nutt.) frequently attacks the Emory oak, evidently gaining entrance in the younger portions of the twigs. The clusters of mistletoe rob the limbs attacked of a portion of their nutrition, often causing the outer portion to dwindle and die. Severe attacks stunt the trees, and may in extreme cases kill them.

OTHER INJURIES.

Occasional terrific hailstorms of a local character defoliate whole stands, break tender shoots, and even scar the branches. A few trees are girdled and killed by lightning.

UTILIZATION.

While there has been a limited utilization of Emory oak for poles, posts, and mine timbers, it is used almost exclusively for fuel, for which it is preferred to the other woods of the region. Where Emory oak sells at $5 a cord for domestic firewood, the other oaks sell at from $3.50 to $4. At the mines the usual price for Emory oak is $3, and there is not a ready sale for the other oaks at $2. It is commonly reputed to make a hotter fire and to leave less ash; yet the comparative showing of Arizona white oak, under a careful test, indicates that there is no warrant for the existing strong prejudice against it. The results of this test are given in Table 3.

TABLE 3.—*Comparison of the heating values of Emory oak and Arizona white oak.*[1]

Part of tree.	Proportion of ash.		Heating value per pound.		Heating value of oaks compared with available coal and oil supplies per unit of weight.					
					Emory oak.			Arizona white oak.		
	Emory oak.	Arizona white oak.	Emory oak.	Arizona white oak.	Dawson coal.	Cerillos anthracite.	Bakersfield crude oil.	Dawson coal.	Cerillos anthracite.	Bakersfield crude oil.
	P. cent.	*P. cent.*	*B.t.u.*[2]	*B.t.u.*[2]	*P. cent.*	*P. cent.*	*P. cent.*	*P. cent.*	*P. cent.*	*P. cent.*
Trunk, average	3.70	7.36	8,339	7,499	67	63	43	60	57	39
Heartwood	12.47	3.70	7,497	8,239	60	56	39	66	62	43
Sapwood	2.54	5.53	8,203	7,620	66	62	43	61	57	40
Bark	9.13	17.38	7,839	5,618	63	59	41	45	42	29
Top, average	4.65	3.09	8,080	8,244	65	61	42	66	62	43

[1] Determined by H. S. Betts, Forest Service. [2] British thermal units.

Table 3 shows that the heat value of an average sample, including heartwood, sapwood, and bark, from a butt cut, is about 10 per cent less in Arizona white oak than in Emory oak. The greatest difference is in the bark, Emory oak being 28 per cent better than the white oak. Since there is confusion in the popular mind between white oak and blue oak, which is admittedly inferior as a fuel, this may be an explanation of a part of the prejudice; but men

FIG. 1.—A VETERAN EMORY OAK TYPICAL OF THE LOW BROAD VALLEYS.

FIG. 2.—THE EFFECT OF POLLARDING OLD EMORY OAK; ONE OF THE TREES HAS BEEN KILLED.

who have used the three species and who readily identify them favor Emory oak, probably because its wood is more sound and less subject to heart rot than the other two species.

CORDWOOD.

Most of the cordwood is cut by Mexicans, who prefer the ax to the saw, as most woodsmen do; in their case, however, part of the preference for the ax is due to their inability to keep a saw in proper shape to do good work. Before the establishment of the National Forests in the region studied it was their custom to pollard large trees, or those which they thought would be hard to split. Even when trees were felled the stumps were likely to be 3 feet high. They never made a clean cutting, and although their wastefulness may be condemned as far as individual trees are concerned, the resultant effect on the forest has been better than that which would have followed indiscriminate clean cutting.

The wood is supposed to be cut and stacked into cords; yet not a single full cord was found in Nogales or at any of the mining camps. Instead of 4-foot lengths, the sticks were not more than 3½ feet long, and, where the buyer was unsuspecting, not more than 3 feet. Every effort is made to make the stack look large with the least possible amount of wood. The branches are crooked, and the piles are as loose as they can be made—as the saying is, "so you could throw a dog through them anywhere." Under these conditions the actual solid content of wood is much short of what it should be and of what it would be if the sticks were cut full length and were well stacked. The usual short cord contains about 65 cubic feet, whereas a full cord should contain about 72 cubic feet, or about 10 per cent more. With the usual 3½-foot stick length, 65 cubic feet can be used as a converting factor for cordwood volume tables.

Table 4 gives the solid cubic contents of Emory oak trees in cubic feet by diameter at breastheight:

TABLE 4.—*Cubic contents of Emory oak, of various diameters.*[1]

Diameter, breast high.	Volume.	Basis trees.	Diameter, breast high.	Volume.	Basis trees.
Inches.	*Cubic feet.*	*Number.*	*Inches.*	*Cubic feet.*	*Number.*
3	0.5	20	17	41.0	4
4	.9	35	18	49.5	5
5	1.6	12	19	59.0	1
6	2.4	10	20	68.7	3
7	3.4	7	21	78.4	1
8	4.5	9	22	89.7	4
9	6.0	15	23	101.8	1
10	8.0	4	24	113.8	3
11	10.4	9	25	126.0	2
12	13.4	7	26	140.0	2
13	17.0	6	27	155.0	2
14	21.5	2	28	170.0	1
15	27.0	7			
16	33.5	4	Total..	.....	176

[1] Includes trees over 3 inches in diameter and cordwood sticks down to 1½ inches middle diameter.

TANNIN POSSIBILITIES.

The use of the tannin content of Emory oak has often been suggested, although the tannin would be very dark colored unless clarified. In the scarcity of other tannic agents it ought to furnish the supply for an industry in its region. Table 5 shows the quantity and sources of the tannin in the three most prominent oaks of Arizona.

TABLE 5.—*Tannin content of the different parts of Emory oak, Arizona white oak, and blue oak.*

Species.	Live or dead section.	Location of section.	Sample.	Insoluble solids, reds, etc.	Soluble solids.	
					Non-tannin.	Tannin.
				Per cent.	*Per cent.*	*Per cent.*
Q. emoryi	Live	Base of trunk	Bark (32.5 per cent)	2.1	6.6	7.4
			Wood (67.5 inches)	.8	4.4	3.1
			Average	1.2	5.1	4.5
		Ultimate branches.	Total	.7	5.7	3.7
		Twigs	do	.8	7.2	2.6
		Twigs and leaves	do	1.5	5.8	2.7
	Dead	Lower branch of 12-inch tree.	Bark (33.3 per cent)	.6	3.3	2.9
			Wood (66.7 inches)	.6	2.5	1.8
			Average	.6	2.8	2.2
		Lower branch	Bark (28.7 per cent)	1.2	4.9	5.4
			Wood (71.3 inches)	.8	4.9	3.4
			Average	.9	4.9	4.0
Q. arizonica	Live	Base of trunk	Bark (27.8 per cent)	1.4	5.7	3.1
			Wood (72.2 inches)	.9	7.3	1.7
			Average	1.0	6.9	2.1
		Branch 5 feet above ground on 12-inch tree.	Bark (26 per cent)	1.0	2.7	2.6
			Wood (74 inches)	1.1	5.9	5.8
			Average	1.1	5.1	5.0
		Ultimate branches.	Total	.6	5.1	3.1
	Dead	Lower branch	Bark (13.9 per cent)	3.7	4.0	3.0
			Wood (86.1 inches)	1.0	4.1	3.8
			Average	1.2	4.1	3.7
Q. oblongifolia	Live	do	Bark (27.3 per cent)	.9	4.7	2.4
			Wood (72.7 inches)	.8	6.1	4.5
			Average	.8	5.7	3.9
		Branch	Total	.5	5.2	1.9

According to Table 5, Emory oak shows a fairly rich tannin content—7.4 per cent—in the bark at the base of the tree, as compared to the average for American tanbarks of about 10 per cent. The prospects for the commercial use of Emory oak are limited to the Southwest, but they seem so good there that its possibilities should be thoroughly studied.

OTHER USES.

There is but little activity in mining in the region, but even in the past, when the mines were being worked, Emory oak was rarely used for mine timbers. Yet most of the available conifers have been cut, and, as the region is very rich in minerals, there is likely to be a strong local demand for mine timbers, for which Emory oak will be used to some extent with other native oaks.

Though it is not of high value for posts, there is a limited use, in the absence of good post material.

MANAGEMENT.

Two principal recommendations are at the basis of the very simple rules necessary to the proper management of Emory oak: One is to keep fires out; the other is to prohibit cutting from July to September, and especially in August. The best results in securing coppice growth will accrue from a system which confines cutting to the period from November to April, inclusive.

The stands of large trees in the broad open valleys are the hardest to reproduce. Badly defective trees should be cut, and the density of the stand increased by protecting the shoots from stock. Since the range animals are not herded, and fences are out of the question, a trial might be made of piling brush over the stumps to protect the young coppice. This will, of course, increase the likelihood of injury by fire, but these stands are more easily protected from fire than from grazing.

In the narrow valleys and on the slopes reproduction is more assured. The stools are smaller, and have a stronger sprouting capacity than the large trees in the broad valleys. Because of this difference in size, it is easier to cut low stumps in the small stands. To save wood, the saw should be used in felling and in cutting up the timber above 6 inches in diameter. In thicket stands, where there are several sprouts to the stool, if the poorer ones are thinned out it will give the better sprouts the advantage of increased light.

Clear cutting should never be practiced, and the wasteful pollarding practiced by the Mexican woodchoppers, bad as it was, is preferable, as a sort of rough selection system, to a clear cutting, which tends to lay bare a large area and render all the unprotected new growth susceptible to all sorts of injuries.

Approved.

JAMES WILSON,
Secretary of Agriculture.

WASHINGTON, D. C., *March 2, 1912.*

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HENRY S. GRAVES, Forester.

QUEBRACHO WOOD AND ITS SUBSTITUTES.

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QUEBRACHO WOOD AND ITS SUBSTITUTES.

WOODS CALLED QUEBRACHO.

Quebracho (*Quebrachia lorentzii* Griseb.), a South American wood yielding a valuable extract much used in the United States for tanning high-grade leathers, is not the only wood known by that name. Two other and inferior species, *Aspidosperma quebracho-blanco* Schlecht and *Aspidosperma quebracho-colorado* Schlecht, are called white quebracho, or "quebracho blanco, " and red quebracho, or "quebracho colorado," respectively. These two, however, belong to an entirely different family (*Apocynaceae*), including the common dogbane or Indian hemp, from the true quebracho, which is a member of the sumac family (*Anacardiaceae*). The name quebracho is derived from two Portuguese words, "quebrar," meaning break, and "hacha," ax, in allusion to the extreme hardness of the wood. At one time nearly every South American wood that quickly dulled an ax was called quebracho, but to-day the three woods mentioned are the only ones of commercial importance to which the name is applied.[1] This indiscriminate use of the name quebracho naturally has resulted in much confusion regarding the identity, distribution, and uses of these woods, and the purpose of this circular is to give the uses and distinguishing characteristics of each. Throughout, the true quebracho will be referred to simply as quebracho, while the two other species will be called white quebracho and red quebracho, respectively.

DISTRIBUTION AND SUPPLY OF QUEBRACHO.

Quebracho is found in Argentina, Bolivia, Brazil, Paraguay, and Uruguay. (See map.) It is distributed from the Andes eastward for approximately 500 miles, and from near the mouth of the Parana River northward for about 600 miles, thus growing over a territory of 300,000 square miles. A few writers claim that the Province of Santiago, Chile, once yielded quebracho, but nothing definite exists to show that it ever extended that far westward. Its commercial range is confined chiefly to northern Argentina, in the Provinces of Tucuman, Santiago del Estro, and Santa Fe, and the Territories of Formosa

[1] In Porto Rico a sapindaceous shrub (*Thouinia stricta* Radlk.), noted for its very hard wood, is called quebracho. In Cuba there is a "quebracho" tree (*Copaifera hymenæifolia* Moric.), belonging to the bean family (Leguminosae). In Chile and Honduras the name quebracho is given to a species of *Acacia*, another member of the bean family. "Quebracho flojo" or "sombra de toro" (*Iodina rhombifolia* H. and A.) is a handsome evergreen tree of Argentina belonging to the sandalwood family.

and the Chaco, and to the Chaco of Paraguay. It is comparatively rare in Bolivia and Uruguay, and in the Provinces of Salta and Jujuy, Argentina.

At the present rate of consumption, the supply of quebracho appears to be practically inexhaustible. Owners of quebracho timber claim that an average acre yields approximately 2 tons of the wood. A very conservative estimate of the total possible yield from the areas where quebracho occurs in commercial quantity places it at 168,000,000 tons, while the present yearly consumption of the wood for all purposes is a little less than 1,000,000 tons. The consumption, however, because of the scattering way in which quebracho grows, entails the cutting over each year of about 500,000 acres.

The price of quebracho lands varies greatly. In Paraguay they bring, as a rule, from $6,000 to $7,000 per square league,[1] (approximately 4,633 acres), or about $1.50 per acre, though some areas can be purchased for as little as from 15 to 25 cents per acre. In the Argentine Chaco, on the other hand, certain tracts near railroads or waterways sell for $2 per acre or more.

THE QUEBRACHO TREE.

Quebracho never grows in pure stands, but is scattered through open forests composed of many species. Seldom, in fact, are more than four or five quebracho trees found on an acre. It usually attains a height of from 50 to 70 feet, and a diameter of from 2 to 4 feet. It is neither a mountain nor a river-bottom tree, but grows best in the somewhat elevated stretches between the water courses, or in other situations with sandy soil and moderate atmospheric and abundant soil moisture. Its growth during early life is very rapid, fence posts being obtained in 10 years, but in later life is very slow. Little is known, however, concerning its average rate of growth to maturity. So far it has been free from attack by insects.

QUEBRACHO WOOD.

The heartwood of quebracho is one of the hardest, heaviest, and, in the region of its occurrence, most durable woods known. Highly tempered tools are required to work even the young green wood, and old wood is almost as hard as metal. It weighs about 78 pounds per cubic foot, and has a specific gravity of from 1.2 to 1.4, sinking, of course, in water. Nine quebracho ties of the size used in Argentina weigh a ton. Its lasting qualities are such that, in Argentina, ties of the wood appear to remain indefinitely in a perfect state of preservation. Logs left in the woods have been found absolutely sound after 25 years. The wood contains a very large amount of tannin, which

[1] Daily Consular Report, January 11, 1911.

FIG. 1.—Distribution of the quebracho tree (*Quebrachia lorentzii*).

acts as a preservative, and to which its extraordinary durability has been ascribed.

The sapwood of quebracho, forming about one-third of the whole, is nearly white. The heartwood, when freshly cut, is dark cherry-red, but becomes much darker with age. It is fine-grained and takes a beautiful polish. When thoroughly seasoned it does not warp, nor is it likely to check during seasoning.

USES OF THE WOOD.

GENERAL.

Quebracho wood is one of the principal commercial products of South America. Though its qualities fit it for use in many ways, its value for tanning extract and crossties is so great that nearly the entire annual cut is put to one or the other of these uses. In Argentina, however, where it is commercially most important, quebracho is employed for more purposes, though not in greater quantity, than any other wood.

There, because it is proof against decay, it finds place in wharves, dry docks, and quays, and as fence posts, beams, and cross arms. It is also used for bridge and ship building, general construction, furniture, and interior finish. The timber is usually seasoned for from two to four years before being used.

CROSSTIES.

Quebracho has been adopted throughout its range as a standard crosstie timber, and is gradually replacing the cast-iron ties once common. In Argentina quebracho ties for broad-gauge roads are 9 feet long, 10 inches wide, and 8 inches thick, and sell for from $2 to $2.50 each. The wood is so hard that spikes can not be driven into it, and holes must be bored clear through a tie for bolts to fasten the rails. About 18 quebracho ties are got from the average acre, a yield which appears small when contrasted with the 40 to 60 first-class white oak or pine ties obtained from an acre of our native forest. The difference is compensated, however, when it is remembered that the life of a quebracho tie may be practically indefinite, while that of our best native ties is seldom greater than eight years. Practically all the quebracho cut for ties is used in South America. Quebracho ties have been tried experimentally in the United States, but were found to lack resiliency and to crack badly with frost. The expense of boring holes for bolts was also another item against them.

TANNIN EXTRACT.

The heartwood of quebracho yields from 20 to 24 per cent of tannin, the sapwood from 3 to 4 per cent, and the bark from 6 to 8 per cent. It is this remarkable production, varying in different parts of the

tree's range, which justifies the extensive use for tan extract of a wood so valuable for other purposes. The bark and sapwood are seldom utilized, a fact which seems to indicate unnecessary wastefulness, since the tannin content of the former is equal to that of the lower grades of our native tanbarks; while the content of the latter is but slightly below that of our native chestnut wood.

Besides tannin, quebracho wood contains considerable, though relatively small quantities of red, gambier-like coloring matter used as a filler. Quebracho extract does not contain enough of the nontannin materials to produce by itself well-nourished leathers, and is therefore mixed in the proportion of 1 to 4, by weight, with other tannin material, such as the extracts of mangrove and chestnut, which are stronger in nontannin substances.

When cut for tan extract the trees are cleaned of their bark, sapwood, and branches, and then brought to the factory, where they are reduced to shavings or small chips. These are boiled or steamed to release the tannin, and the resulting fluid extract is evaporated to a thick paste, which, when dry, goes to the market in sacks or barrels. The cost of cutting quebracho logs and bringing them to the factory is much greater than that of manufacturing the extract itself. At present logs are hauled chiefly by ox teams to the nearest railroad or boat landing, and from there shipped to the reducing mill. It is in Paraguay, where quebracho trees are very scattered, that the transportation of logs is most difficult and expensive. Little or no market exists for quebracho timber or extract there, and practically all of the wood is shipped to Buenos Aires, where it is either consumed for extract or exported.

Quebracho obtained from the Provinces of Santiago del Estero and Santa Fe, Argentina, is particularly rich in tannin, and there also the trees reach their largest size. It is chiefly in these Provinces that quebracho is being extensively lumbered, the output steadily increasing from year to year. In the Provinces of Salta and Jujuy, where quebracho is rare, the inhabitants prefer for tannin the bark of two trees, *Acacia cebil* Griseb. and *Piptadenia cebil* Griseb., locally known as cebil. These barks are exceedingly rich in tannin material, in the case of the latter, at least, containing from 19 to 25 per cent.

IMPORTATION OF QUEBRACHO INTO THE UNITED STATES.

Quebracho wood and extract are now the leading exports of Argentina and Paraguay. Since their introduction in 1888, imports of these into the United States have increased steadily. In 1910, 38 per cent of all the tannin material used in the United States was quebracho. Nearly all of this came from Argentina. Table 1 shows the quantity and value of material imported during the fiscal years 1907 to 1910, inclusive.[1]

[1] Compiled from Bureau of Statistics Bulletins 76 and 90, Imports of Farm and Forest Products.

TABLE 1.—*Imports of quebracho wood and extract into the United States, 1907–1910.*

Year.	Wood.		Extract.	
	Tons.	*Value.*	*Pounds.*	*Value.*
1907	66,810	$840,779	76,033,584	$2,319,785
1908	48,871	612,971	79,186,787	2,260,364
1909	66,113	731,795	102,004,981	2,740,530
1910	80,210	1,058,647	95,183,073	3,021,902

Quebracho wood enters the United States free of duty. A duty of from one-half to three-fourths of a cent per pound, however, is levied on the extract, which, in the new (1909) tariff schedule, is divided into two classes, according to its density or the percentage of tannin it contains. If less in density than 28° Baumé [1] the duty is one-half cent; if greater it is three-fourths of a cent. Transportation from Argentina to the United States is so cheap that many importers bring in logs and extract the tannin in this country, thus saving the high import duty. The price of quebracho extract f. o. b. Montevideo or Buenos Ayres, the two principal exporting points, is from $80 to $85 per ton, and that of logs from $14 to $20 per ton.

SUBSTITUTES FOR QUEBRACHO.

Both of the other woods which go to the market as quebracho, the white and the red, yield a relatively low percentage of tannin, and it is therefore unlikely that they are knowingly substituted to any extent for the true quebracho. Often, however, they may unintentionally be substituted for quebracho, through similarity of names. Quebracho is frequently called quebracho colorado, and red quebracho is also called this, and often merely quebracho. White quebracho, too, goes under the latter name. While quebracho and red quebracho may resemble each other superficially, white quebracho is readily distinguished from either by its light color. White quebracho is commercially more important than the red, and in some parts of South America has been used as a substitute for quebracho. It yields a much lower percentage of tannin, but the tannin itself is not essentially different from that of quebracho.

WHITE QUEBRACHO (QUEBRACHO BLANCO).

White quebracho is common throughout the regions where quebracho grows. It is most abundant in the wetter parts of northern Argentina, in the Provinces of Cordova, Santa Fe, Catamarce, Santiago del Estero, the southern portion of Tucuman, and the Chaco. It is an evergreen tree, reaching a height of from 60 to 100 feet, a

[1] An arbitrary scale devised by Baumé. It may be reduced to specific gravities by the following formulas: (*a*) For liquids heavier than water, sp. gr. $=\frac{144}{144-X}$. (*b*) For liquids lighter than water, sp. gr. $=\frac{144}{134+X}$, X in each case being the reading by Baumé's scale.

diameter of from 1 to 3 feet, and remarkable for its erect stem and wide spreading crown. It is usually less bulky than quebracho, and branches nearer the ground, features which help to distinguish it in the forest.

The wood is strong, hard, and very heavy (specific gravity from 0.88 to 1.1), very close-grained, yellowish white in color, with a pinkish or rosy tint. It is not very durable in contact with the soil, yet much in demand for fence posts, rafters, flooring, railroad trucks, crossties, cabinet work, turnery, hubs, spokes, and cogwheels. Its dense, uniform structure makes it suitable as a substitute for boxwood (*Buxus sempervirens L.*) in wood engraving. Unless very carefully seasoned, however, it is likely to warp and twist, and is said to be subject to insect attack.

RED QUEBRACHO (QUEBRACHO COLORADO).

Red quebracho is also abundant throughout quebracho's range. Its wood when freshly cut is red, but becomes dark brown with age. It is used for practically the same purposes as white quebracho. Although in general its structural characters are similar to those of the former, it is said to be more durable in contact with the soil. While red quebracho may at first sight be mistaken for quebracho, its structural characters distinguish it. Moreover, its commercial importance is relatively so small that it is seldom mixed with the other wood.

KEY FOR THE IDENTIFICATION OF QUEBRACHO WOOD AND ITS SUBSTITUTES.

As an aid in distinguishing the wood of quebracho from that of the two inferior species, a key is given, in which are included such gross characters of the woods as may be seen in a smooth transverse section with the aid of a hand lens. For the use of students, several of the minute characters, which can be seen only under the high power of a compound microscope, are also included. Plates I and II show magnified transverse sections of quebracho and white quebracho wood. The structure of red quebracho is so similar to that of white that an illustration of it is unnecessary.

Pores (*vessels*) small (0.03 to 0.09 millimeters), open, and regularly distributed; tangential bands of large pores usually alternating with bands of smaller pores. *Wood-parenchyma fibers* abundant, scattered throughout the wood, often arranged in short tangential lines. *Wood fibers* 0.9 to 1.5 millimeters long. *Heartwood* dark pink, hard, and heavy (about 62 pounds per cubic foot).

(*Aspidosperma quebracho-blanco* Schlecht.)

Similar in structure to above, but heartwood red, becoming dark brown with age.

(*Aspidosperma quebracho-colorado* Schlecht.)

Pores (*vessels*) larger (0.10 to 0.13 millimeters), closed (in the heartwood) and irregularly distributed, usually grouped in radial rows of from two to four. *Wood-parenchyma fibers* confined to proximity of vessels, often forming conspicuous groups. *Wood fibers* very small in diameter (0.5 to 1.2 millimeters long). All cells of the heartwood are crowded with a yellowish-brown substance. *Heartwood* dark cherry-red, very hard, and heavy (about 78 pounds per cubic foot).

(*Quebrachia lorentzii* Griseb.)

Approved:

JAMES WILSON,
Secretary of Agriculture.

WASHINGTON, D. C., *March 15, 1912.*

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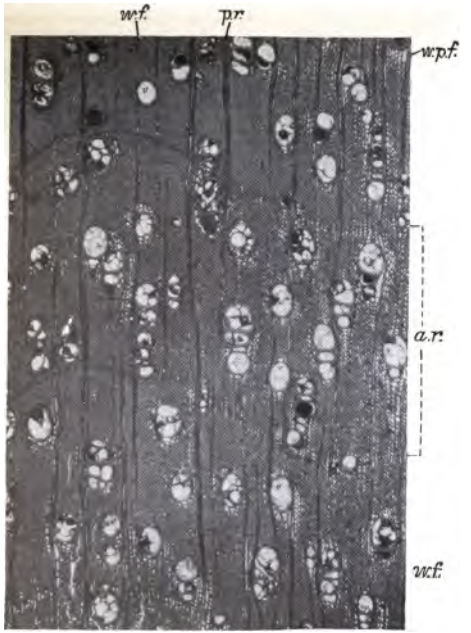

Fig. 1.—Transverse section of the wood of quebracho (*Quebrachia lorentzii*) showing one entire annual ring of growth (*a. r.*); *v.*, vessel; *w. f.*, wood fibers; *w. p. f.*, wood-parenchyma fibers; *p. r.*, pith ray. Magnified 25 diameters.

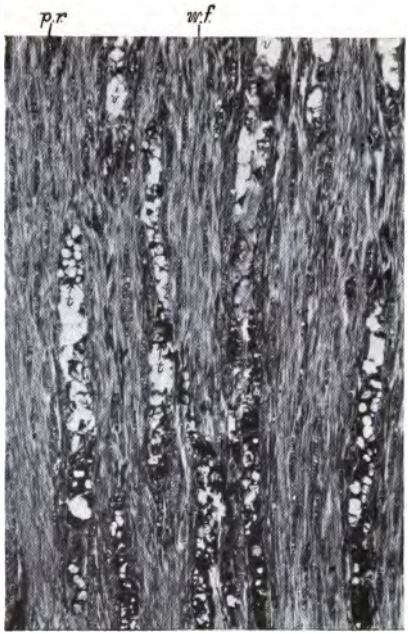

Fig. 2.—Tangential section of the wood of quebracho (*Quebrachia lorentzii*); *v.*, vessel; *p. r.*, pith ray; *w. f.*, wood fibers; *t.*, tyloses. Magnified 25 diameters.

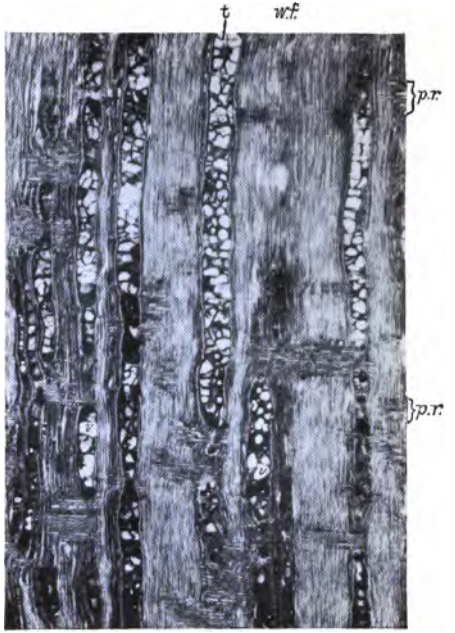

Fig. 3.—Radial section of the wood of quebracho (*Quebrachia lorentzii*); *v.*, vessels; *w. f.*, wood fibers; *p. r.*, pith rays; *t.*, tyloses. Magnified 25 diameters.

THE WOOD OF QUEBRACHO.

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PLATE I.

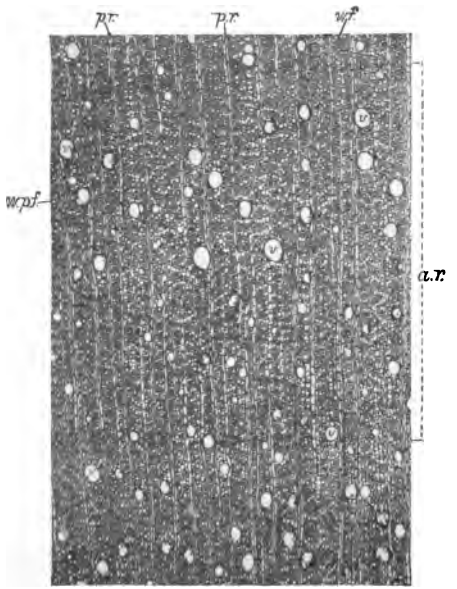

Fig. 1.—Transverse section of the wood of white quebracho (*Aspidosperma quebracho-blanco*) showing parts of two annual rings of growth: *v.*, vessels; *w. f.*, wood fibers; *w. p. f.*, wood-parenchyma fibers; *p. r.*, pith rays. Magnified 25 diameters.

Fig. 2.—Tangential section of the wood of white quebracho (*Aspidosperma quebracho-blanco*); *v.*, vessel; *w. f.*, wood fiber; *w. p. f.*, wood-parenchyma fiber; *p. r.*, pith ray. Magnified 25 diameters.

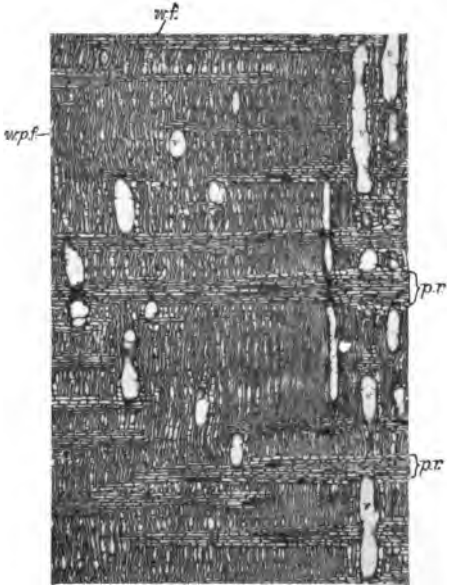

Fig. 3.—Radial section of the wood of white quebracho (*Aspidosperma quebracho-blanco*); *v.*, vessel; *w. f.*, wood fibers; *w. p. f.*, wood-parenchyma fibers; *p. r.*, pith rays. Magnified 25 diameters.

THE WOOD OF WHITE QUEBRACHO.

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Issued April 9, 1912.

U. S. DEPARTMENT OF AGRICULTURE,

FOREST SERVICE—CIRCULAR 203.

(SUPERSEDES CIRCULAR 165.)

HENRY S. GRAVES, Forester.

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ASSISTANCE TO PRIVATE OWNERS IN THE PRACTICE OF FORESTRY.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1912.

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ASSISTANCE TO PRIVATE OWNERS IN THE PRACTICE OF FORESTRY.

MORE PRODUCTIVE USE OF FOREST AND WASTE LANDS POSSIBLE.

The forests of the United States, because of repeated fires and unwise cutting, are at present producing a small fraction of their possible yield. By scientific cutting many woodlands can be made to produce from one-third to two-thirds more useful material and a much larger proportion of the more valuable kinds of wood. Extensive areas of waste land suited only to tree growth are now largely unproductive. If planted to forest trees, they would yield substantial returns. Small areas of woodland for producing fuel and fencing or to furnish windbreaks are needed on many farms. As the supply of timber in the country decreases the better use of forest and waste land is becoming of more importance and value to the private owner. This circular points out the means and kind of assistance in this work which are at his disposal.

WHAT PRIVATE OWNERS NEED TO KNOW.

Protection from forest fires must precede the practice of forestry.

Protecting forest lands from fire. The majority of private owners need direct information and advice on protective methods adapted to their lands.

Many owners need technical information which will enable them

Planting waste land. to reforest unproductive lands not adapted to farming, or to establish windbreaks or shelterbelts. Such owners need to know how to start and care for plantations, what species to plant, how fast they grow, and what financial returns may be expected from planting.

The greatest need of the average woodlot owner is advice on how

Cutting woodlands. to cut his timberland so as to perpetuate and improve it. The usual methods of cutting result too often in depleting the wood-producing capacity of the forest and impairing its permanent value. In many instances such destructive methods can be changed in simple, practical ways which will increase the productiveness and value of woodlands without seriously restricting their present use.

WHERE ASSISTANCE MAY BE OBTAINED.

The services of private or consulting foresters can now be secured.

Consulting foresters. These men will advise owners on all matters connected with forestry. They will outline systems of fire protection, prepare plans for tree planting or the cutting of timberlands, and supervise operations on the ground, if desired. Expert advice

on such matters as shade trees, landscape gardening, and tree surgery is also available.

State foresters.

A number of the States have established forestry departments in charge of a State forester, who assists private owners. In several States advice is furnished on the ground by a detailed examination of woodlots or areas to be planted with forest trees. Many of the States distribute free publications on forestry. A few of them furnish their citizens with forest-planting stock at cost price for reforestation purposes within the State.

Forest Service.

The Forest Service of the Department of Agriculture also assists private owners. It often accomplishes this best by referring applications from small owners within States having forest organizations to the proper State officer. This is especially true where woodlot examinations are desired. The State forester is in closer touch with local conditions within his State. Moreover, he can usually make examinations at less expense to the owner than is possible for the Forest Service.

Applicants for assistance in the management of large forest properties are usually referred by the Forest Service to private or consulting foresters. The Service is not now equipped to examine large tracts and prepare plans for their management. With trained foresters available elsewhere, it is no longer necessary for the Government to assume this work for large owners.

HOW THE FOREST SERVICE ASSISTS PRIVATE OWNERS.

Lists of State and private foresters.

Applicants desiring examinations of timber holdings whom the Service can not help directly are supplied with a list of private or consulting foresters. If their State has a forester, they are given his name and address.

Lists of dealers in planting stock.

Owners who desire to obtain planting stock, either seeds or young trees, with which to reforest waste lands or establish farm woodlots or windbreaks, are supplied with lists of dealers in such stock. The Forest Service has no plant material for distribution. The only exception is in the case of settlers in the Kinkaid district, Nebraska, to whom planting stock from the Halsey nursery will be furnished, in accordance with the act of March 4, 1911.

Distribution of publications.

One of the principal means of assisting private owners is in the preparation and distribution of publications on forestry. These include (1) "planting leaflets," which briefly describe the principal species adapted to various parts of the United States and methods of planting them; (2) commercial tree bulletins, which deal with the characteristics and scientific treatment of the more important commercial species, as they occur in natural stands; and (3) a series of "regional studies," which discuss questions of forest management, planting, and utilization with reference to the needs of private owners within regions where the conditions as to forest growth and markets for wood products are comparatively uniform. Publications of the last two kinds are limited in number, but will be increased as rapidly as possible. Other publications dealing specifically with markets and wood uses are issued from time to time. A complete list of the available Forest Service publications will be furnished upon application.

When information contained in publications will not meet the exact needs of an owner, the Forest Service endeavors to give him specific advice by correspondence. This is especially applicable to tree planting.

Specific advice by correspondence.

In a limited number of cases the Forest Service is prepared to supply owners with detailed advice regarding the practice of forestry based upon examinations of their tracts.

Specific advice based upon examination of the tract.

COOPERATIVE EXAMINATIONS.

Cooperative examinations of private timberlands are restricted mainly to States not equipped to furnish their citizens with expert advice, and to the smaller timber holdings within such States. The majority of such examinations are of tracts ranging in area from 5 to 300 acres.

For whom examinations are made.

Unless half a dozen or more examinations can be made within a more or less restricted area at the same time, the expense incident to the work would scarcely be justified. It is sometimes possible to make a single examination in connection with other field work in the same region. As a rule, however, an applicant is asked to interest several of his neighbors within the same or adjoining counties to make joint application with himself for the examination of their lands at the same time. Since the educational value of the work as well as its economy is greatly increased by cooperating with groups rather than with individuals, cooperative assistance is, wherever practicable, conducted on this basis.

Cooperation with groups of applicants.

After an examination, a report is prepared for the owner giving:

(1) Suggestions on the best methods of managing the woodlands, with specific recommendations on marking trees for cutting.

Kind of advice given the owner.

(2) Suggestions on the most valuable uses of the timber and the most profitable means of marketing it.

(3) Where tree planting is recommended, detailed instructions on planting the area examined; a list of the best species to plant; suggestions on planting methods; kind of planting stock to produce or purchase; and the care of the plantation.

It is usually possible to furnish satisfactory advice on planting by correspondence. This obviates the expense of field examinations. In such cases the owner should carefully describe the character of the proposed planting site by filling out the blanks in Form 728, on page 7 of this circular. Additional copies of this form will be furnished upon application.

The Forest Service can not assist owners in:

(1) Preparation of detailed estimates of standing timber.

What the Forest Service can not give the owner.

(2) Preparation of scientific data or furnishing expert advice of any kind for use in litigation.

(3) Supervision of cutting or planting operations.

(4) Furnishing seed or planting stock, with the exception noted on page 4 in the case of residents in the Kinkaid district, Nebraska.

(5) Examinations for the purpose of giving advice on the care of ornamental trees or groves, or on the management of forests where the owner is chiefly interested in landscaping or parking rather than

in the practice of forestry for wood production. Consulting foresters, tree "doctors" and landscape experts are readily obtainable for these lines of work.

Cooperative examinations for private owners are made by the Service in accordance with the following terms:

Regulations governing private cooperation.

The Forest Service pays the salary of its expert while engaged upon the examination. The owner pays his traveling and living expenses. If a special trip is necessary, these expenses are charged from Washington, or one of the district headquarters in the West, to the tract and return. The district headquarters are at Missoula, Mont.; Denver, Colo.; Albuquerque, N. Mex.; Ogden, Utah; San Francisco, Cal.; and Portland, Oreg. If a member of the Service is in the region from which the application is made, his expenses are charged from the nearest point on his route and return. Where several examinations are made within the same region, the total expenses are apportioned among the respective owners who are assisted. Applicants for assistance are required to deposit in advance a sum sufficient to cover the estimated expenses, with the understanding that any unexpended balance of the deposit will be refunded at the completion of the work.

What the Forest Service expects of owners whom it assists.

No examination will be made by the Forest Service unless the owner expresses a readiness to take definite steps toward improved management of his forest lands and agrees to carry out as far as he finds practicable the recommendations contained in the report prepared for him. The Service further expects that the owner will assist its expert as far as possible in making the examination, and that he or his representative will accompany the expert over the property. It is also understood that the owner will furnish reports from time to time as requested by the Service on the work done, its cost, financial returns, and actual results.

HOW TO SECURE THE ASSISTANCE OF THE FOREST SERVICE.

Those who desire assistance from the Forest Service under the provisions of this circular should fill out one of the two forms given herein—Form 704 for the examination of forest lands, and Form 728 for assistance in tree planting—or make application to the Forester at Washington, D. C., or to the nearest district forester, stating the kind of assistance desired. Assistance which can be rendered by sending publications or by correspondence will be furnished immediately. If a field examination is necessary and can be undertaken by the Service, the application will be filed and arrangements made with the owner for an examination of the tract at the earliest practicable date.

SPECIAL COOPERATIVE ARRANGEMENTS.

In addition to direct cooperation with private owners, the Forest Service will make special cooperative arrangements, as far as its resources permit, with States, agricultural colleges, boards of trade, and similar organizations for the purpose of interesting small owners in the practice of forestry. Such cooperation may take the form of organizing forestry clubs among private owners or of furnishing an expert to conduct field examinations under the direction of the cooperator and in whole or in part at its expense. No set regulations govern cooperation of this character, which will be adapted to the needs and conditions in each case.

(Form 728.)

UNITED STATES DEPARTMENT OF AGRICULTURE—FOREST SERVICE.

APPLICATION FOR EXAMINATION OF LANDS FOR FOREST PLANTING.

....., 19...
(date)

Name of applicant.....

Post-office address.....

Location of tract to be planted.....
(town) (county) (State)

Area of tract on which planting is contemplated.....acres.

Character of land: .....
(level) (rolling) (steep)

Kind of soil: .....
(sandy) (loamy) (clay)

Does the soil contain lime? .....

Depth of surface soil: .....
(Shallow; 6–12 inches) (medium; 12–24 inches) (deep; 24–35 inches)

.....
(very deep; over 36 inches)

.....

Drainage: .....
(poor) (fair) (good)

Has the land been cultivated? ..... If so, for what period, and what crops have been raised? .....

Ground cover—character and extent: .....
(Grass, weeds, shrubs, trees—varieties of each and per

.....
cent of surface bearing them)

What trees thrive in natural woodlots in your neighborhood? .....

.....

Object of planting: .....
(Production of fuel, poles, posts, ties, lumber; as shelter from wind, to protect

.....
soil from erosion, etc.)

When do you desire to plant? .....

Additional information.....

AGREEMENT.—I hereby make application for the examination by the Forest Service of the planting site above described, with the understanding that any planting recommendations will be carried out as far as is found practicable and that reports describing such plantations and their results will be furnished the Forest Service whenever requested.

(Signed).....

[Cir. 203]

(Form 704.)

UNITED STATES DEPARTMENT OF AGRICULTURE—FOREST SERVICE.

APPLICATION FOR EXAMINATION OF FOREST LANDS.

....., 19...
(date)

Name of owner.....

Post-office address.....

Location of tract.....
(town) (county) (State)

Area of tract.....acres.

Character of forest.....
(species, average size)

Condition of forest.....
(Approximate per cent mature, second growth, burned over,

.....
cut over, etc.)

Wishes of owner.....
(State the purpose you desire the forest growth to serve, i. e., production of fuel and

.....
other miscellaneous wood products for home consumption; production of fuel, ties, poles, timber, etc., for

.....
sale)

.....

Additional information.....
(State here any information that may help the agent of the Forest Service

.....
in making the examination of the tract, such as the accommodations available, the name of the person

.....
who will accompany agent, the nearest railroad station, etc.)

.....

AGREEMENT.—I hereby make application for the examination by the Forest Service of the above-described tract, with the understanding that its future management and protection will as far as is found practicable conform to the recommendations of the Forest Service embodied in the report on the examination; and I further agree to supply the Forest Service, when so requested, with reports on the work done, its cost, and the results obtained.

(Signed).....

[Cir. 203]

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STRENGTH TESTS OF CROSS-ARMS.

BY

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STRENGTH TESTS OF CROSS-ARMS.

SERVICE LOADS ON CROSS-ARMS.

Cross-arms must resist forces which are variable in amount and direction. In a line the arms may be subjected to heavy loads under several conditions:

(1) If the wires on one side of a pole are broken, a heavy side pull comes on the cross-arm from the other side. This causes a severe stress in the pole, and, as will be shown later, the pole is more likely to be broken than the cross-arm.

(2) If the wires are heavily covered with sleet and there is a strong wind blowing, there is a pressure on the cross-arms, but here again the stress in the pole will cause it to fail before the cross-arm will give way. Similarly, in changes of direction in the line the sidewise pull of the wires is more severe on the poles than on the arms.

(3) If the cross-arms are at the same level in the line, they can receive no greater strains than those which may be imposed by the weight of the wires, and of adhering ice, and by wind pressure. If, however, the middle pole of three is higher than the poles on either side and the wires are tightly stretched, there is a strong downward pull on the cross-arms. A similar condition might result if a single pole were left standing in a line where the poles on either side had fallen.

It is not necessary to reproduce exactly these stresses in laboratory tests if one test can be devised to cover the most severe conditions and the resistance to the less severe estimated on the basis of that one test. A test was devised in which the load was distributed along the arm, as it is in actual practice. In all of the tests the load was applied vertically for two reasons: First, because the arms are likely to receive their heaviest loads in this direction; second, because from the results it is possible to estimate the resistance of the arms to forces acting in other directions. The test used is also well adapted to show the influence of defects on strength.

MATERIAL TESTED.

The material for the tests described in this circular consisted of 84 six-pin cross-arms 3¼ by 4¼ inches by 6 feet (fig. 1). This number was made up of seven groups and comprised four species: Douglas fir, shortleaf pine, longleaf pine, and southern white cedar.

Group 1—12 arms, Douglas fir.
Group 2—12 arms, shortleaf pine.
Group 3—13 arms, longleaf pine, graded by the manufacturers as 50 per cent heart.
Group 4—11 arms, longleaf pine, 75 per cent heart.
Group 5—12 arms, longleaf pine, 100 per cent heart.
Group 6—12 arms, southern white cedar.
Group 7—12 arms, shortleaf pine, creosoted.

Group 1 originated at a mill at Walville, Wash.; groups 2 and 7 at Buell, Va.; groups 3, 4, and 5 at Hattiesburg, Miss.; and group 6 near Norfolk, Va. Groups 1, 2, 3, 4, 5, and 7 were furnished by the American Cross-Arm Co. and group 6 by the John L. Roper Lumber Co. The tests were made at the Forest Products Laboratory, maintained in cooperation with the University of Wisconsin, at Madison. All arms were open-piled in the laboratory from two to eight weeks before the testing work was begun.

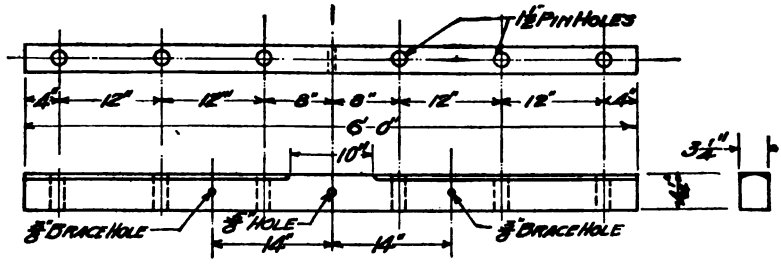

FIG. 1.—Standard 6-foot 6-pin cross-arm.

NOTE. The arms tested varied in height from 3.95 to 4.23 inches and in width from 3.05 to 3.24 inches. Positions of pinholes varied frequently from ¼ to ¾ inch. Brace holes were 16, 18, or 19 inches from center in some groups. Such arms were rebored and brace holes placed 14 inches from center.

METHOD OF TESTS.

Tests were made on a 200,000-pound Riehle universal testing machine. The arrangement of the apparatus is shown in figure 2. The stub pole *f* rests on a short beam on two posts, which in turn rest on the weighing platform. The pole is held in a vertical position by the columns of the testing machine. A gain about 1 inch deep is cut in the side of the pole, and the cross-arm is fastened into it by a ⅝-inch bolt which extends through the pole. That portion of the bolt within the pole is encased in a piece of gas pipe which fits the bolt closely and increases its bearing on the wood. The outer end of this bolt is supported by a heavy brace *b*, consisting of a piece of ½ by 1¾ inch round-edge tire steel, the lower end of which is attached to the pole by a ⅞-inch bolt. The diagonal braces are ¼ by 1¼ inch steel, 24 inches long, from center to center of the bolt holes. The lower ends of these braces are attached to the pole 19½ inches below the center of the cross-arm by a ⅝-inch bolt through the pole, this bolt also being encased in the pole in a piece of gas pipe. The upper

ends of the braces are attached to the cross-arms by ⅝-inch carriage bolts at points 14 inches from the center of the arm and in line with the center bolt.

The center bolt is braced for the reason (found by experimenting on one or two arms) that without the brace the bolt bends and stretches to such an extent that the arm twists or skews out of its

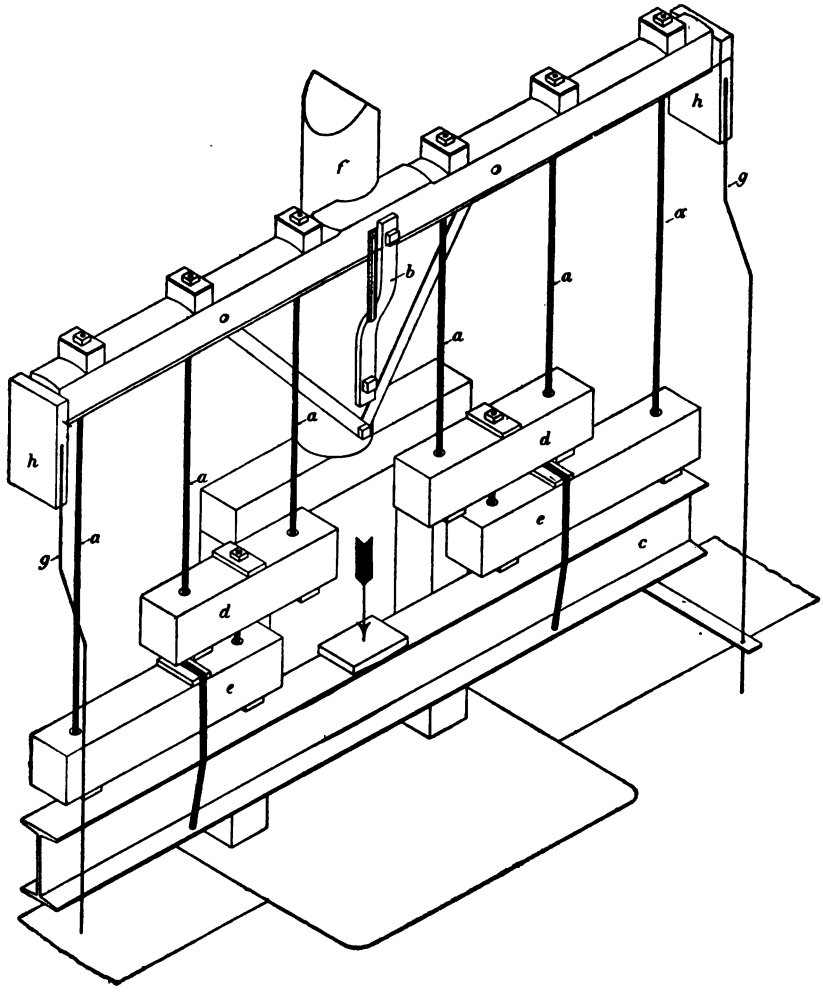

FIG. 2.—Method of testing cross-arms.

original vertical position. The bolts through the poles are encased in gas pipe to give larger bearing on the wood and to prevent too much stress and deformity. While these devices do not conform to those of actual practice, they give more uniform conditions of test.

Blocks, *h*, are each attached to the cross-arm by a nail driven into the center of its end. These blocks are held vertical by the guide

rods, *g*. A nail is driven part way into the front edge of each block and in line with the center of the cross-arm. Between these two nails is stretched a fine wire, which is kept taut by a rubber band. The movement of this wire with respect to a scale in the center of the arm marks the deflection.

The load is applied to the cross-arm by rods passing through the pinholes in the arms. Nuts on these rods pull down on wooden bearing blocks shaped to fit the upper side of the arm. The lower ends of these rods are attached to the system of equalizing levers (*c*, *d*, and *e*), whose arrangement is such that the rods transmit equal loads to the cross-arm.

In conducting the tests an initial load of 250 pounds was applied. The scale and wire were then adjusted to zero reading, the machine started,[1] and a deflection reading taken at 500 pounds and at each increment of 500 pounds until a perceptible weakening of the arm was noted, after which the load was read for each 0.1-inch deflection, and at points of sudden change, until complete failure or 4-inch deflection was secured. A load-deflection diagram was plotted as the test progressed, and from this diagram the values given in the tables were derived. The behavior of the arm during the test was observed carefully, and the character and sequence of the failures described. Each arm was weighed at the time of test.

One arm was tested from each group, then a second arm from each group, and so on, in order that there might be eliminated from the comparison any variation in results due to change in the apparatus. All arms, except four from each group, which were selected to be saved for exhibit, were cut up, and a 1-inch moisture disk and an 8-inch specimen for test in compression parallel to grain[2] were secured from each.

RESULTS OF TESTS.

A detailed summary of the results is presented in Table 1. The load at ½-inch deflection is an approximate measure of the stiffness. "Work to maximum load" and "total work" are measures of the toughness. The maximum load is the measure of the strength or ability to withstand a slowly applied load.

A few of the tests were incomplete or unsatisfactory; while these are included in Table 1, they were omitted from the calculation of the averages which are given in this table. Also, in certain cases the failure of the arms was due, at least in part, to knots and cross-grain. The values obtained in the tests of such arms are printed in italics (Table 1), and these, as well as the tests omitted from the averages

[1] The head descended uniformly at the rate of 0.26 inch per minute.

[2] The compression tests were made in accordance with the procedure described in Forest Service Circular 88, "Instructions to Engineers of Timber Tests."

in Table 1, were omitted in computing the average values given in Table 2.

Since the stresses between the points of attachment of the braces are indeterminate, no allowance has been made for variation in size except to estimate what the maximum loads would have been had the average dimensions of the arms of all groups been the same as those of the Douglas fir group (3.16 by 4.10 inches). These estimated loads are inclosed in parentheses in Table 2.

TABLE 2.—*Summary of results of tests on cross-arms.*

Species and grade.	Rings per inch.	Summer wood.	Sap.	Moisture.	Specific gravity, dry.	Bending tests.				Compression parallel to grain.
						Load at ½-inch deflection.	Maximum load.	Work to maximum load.	Total work.	Maximum crushing strength.
	Number.	*Per cent.*	*Per cent.*	*Per cent.*		*Pounds.*	*Pounds.*	*Inch-pounds.*	*Inch-pounds.*	*Pounds per square inch.*
Douglas fir	20	40	0	11.5	0.479	4,050	7,590 ([1] 7,590)	5,990	15,730	7,080
Longleaf pine, 50 per cent heart	17.9	43.7	55	13.4	.542	4,463	8,984 (9,000)	6,888	13,565	5,425
Longleaf pine, 75 per cent heart	18.5	53	32	13.5	.627	5,220	10,180 (10,240)	7,800	18,370	8,950
Longleaf pine, 100 per cent heart	15.5	44	1	12.8	.627	4,770	9,782 (9,850)	7,970	18,543	8,940
Shortleaf pine	10.5	46	79	13.3	.516	4,460	9,260 (9,220)	8,400	16,510	7,300
Shortleaf pine, creosoted	11.2	49	.....	.....	.....	3,841	7,649 (7,360)	6,084	14,325	5,770
White cedar	12	45	1.5	14.3	.364	2,860	5,200 (4,800)	3,150	6,930	4,700

[1] Values in parentheses are the estimated maximum loads for arms 4.10 by 3.16 inches in cross section (the average size of Douglas fir arms).

COMPARATIVE STRENGTH OF VARIOUS KINDS OF WOOD.

The various species and grades in order of average strength are as follows:

	Average maximum load.
Longleaf pine, "75 per cent heart"	10,180
Longleaf pine, "100 per cent heart"	9,780
Shortleaf pine	9,260
Longleaf pine, "50 per cent heart"	8,980
Shortleaf pine, creosoted	7,650
Douglas fir	7,590
White cedar	5,200

Since the arms with 75 per cent of heart are stronger than those with 100 per cent, and those with 50 per cent are weaker, other factors than the relative amounts of heartwood and sapwood must

have a determining influence on the strength.[1] This is the more apparent in the light of the fact that the actual per cents of heart are, by careful estimate, 100, 68, and 45, respectively, instead of 100, 75, and 50, according to the nominal grading.

There was a very considerable difference in the strength of the natural and treated shortleaf pine arms. Just how much of this difference should be attributed to the treatment it is impossible to determine, but a careful examination of the failures indicates that the creosoted arms were, aside from the treatment, inferior to the untreated.

Both the strength values and the manner of failure show that white cedar is considerably less strong than the other species. The failure is in nearly all cases by short brash tension. The numerous small knots and the large season checks seem to have had little influence on the failures.

INFLUENCE OF DEFECTS.

In nearly all cases the principal failure was at the first pinhole from the center, though in many cases the first failure was apparent as a cracking at the center bolt hole. In view of these facts it is recommended that, in grading or selecting arms, particular attention be given to defects near the center or the first pinholes. Knots on the upper side of the arm near these points are especially to be avoided.

SUMMARY.

The average load borne by the Southern white cedar cross-arms, the weakest group, was 5,000 pounds, the load being applied vertically. By careful estimate the resistance of these arms to side pull is at least 4,000 pounds. Under any conditions of service this is more than sufficient, because it is so much greater than the side load that can be sustained by poles. In tests[2] these have not withstood an average side pull of much more than 3,000 pounds, and usually have failed at less than 2,000. Further, both the pole and cross-arm tests were made on air-dry material, while under actual conditions of use the poles would be weakened by moisture much more than the cross-arms.

---

[1] This finding is in accord with the general results from timber tests of the Forest Service, that heartwood and sapwood are about equally strong.

[2] Pole tests by the Forest Service gave the following figures for the side pull (applied at the top end of the pole) which a 25-foot pole of 7-inch top diameter is able to withstand:

Western red cedar at 15.1 per cent moisture	1,310 pounds.
Lodgepole pine (fire killed) at 16.9 per cent moisture	1,430 pounds.
Engelmann spruce (fire-killed) at 16.3 per cent moisture	1,405 pounds.

Tests by the Pacific Telephone and Telegraph Company gave the following figures for 25, 30, and 35-foot poles having top diameters of 6, 7, 8, and 9 inches:

Western red cedar (Idaho) at 10.1 per cent moisture	2,215 pounds.
Western red cedar (Oregon and Washington) at 15.2 per cent moisture	1,930 pounds.
Port Orford cedar (Oregon) at 12.0 per cent moisture	3,040 pounds.

In the case of sleet or snow, if the ice coating on the wires gives each strand a diameter of 1 inch, a wind pressure of 27 pounds per square foot would be sufficient to break the pole, assuming that the poles have a resistance to side pressure of 2,000 pounds, and are 150 feet apart. Even under these extreme conditions the cross-arm would have to resist stresses equivalent to those imposed by a load of only 875 pounds, applied as in the tests, so that even the weakest of the arms tested would have more than sufficient strength to withstand a force which would break the average pole.

Where there are abrupt changes of grade in a line, as in the case of one pole higher than those adjacent on either side, the downward pull on the cross-arm depends on the stress of the wires and their inclination from the horizontal. If 6 No. 8 wires are stretched to their maximum strength, assumed to be 60,000 pounds per square inch, they can exert a pull of 7,670 pounds. If a cross-arm on the middle pole had the average strength of Southern white cedar, it could not be broken by such a pull unless the pole were at least 45 feet higher than the two at each side, the spans being 150 feet. Such an abrupt change in grade is rare in practice. If the cross-arm were weakened to 60 per cent of its air-dry strength, which would correspond to a green or water-soaked condition, the arm would not break unless the difference in height were at least 25 feet.

All things considered, cross-arms of the species and dimensions tested are strong enough for ordinary use; with longer arms the strength is relatively of much more importance. With the standard 6-foot cross-arm, however, the question of strength need not enter into calculations of line construction, except in the rare case of abrupt change in grade. The ability of the timber to resist decay, and methods of preventing decay, are considerations of greater importance.[1]

[1] See Forest Service Circular 151, "The Preservative Treatment of Loblolly Pine Cross-Arms," by W. F. Sherfesee.

TABLE 1.—*Detailed summary of tests on cross-arms.*

[NOTE.—Italics indicate arms which failed at defects.]

DOUGLAS FIR (SHIPMENT 91).

Piece No.	Rings per inch.	Summer wood.	Sap.	Moisture.	Specific gravity dry.	Bending tests. Arms mounted on stub pole and braced. Loaded at six pinholes.									Maximum fiber stress in compression parallel to grain.
						Height at center.	Width at center.	Load at ½-inch deflection.	Maximum load.	Deflection at maximum load.	Load at 4-inch deflection.	Total deflection.	Work to maximum load.	Total work.	Kind of failure.[1]	
		Per cent.	*Per cent.*	*Per cent.*		*Inches.*	*Inches.*	*Pounds.*	*Pounds.*	*Inches.*	*Pounds.*	*Inches.*	*Inch-pounds.*	*Inch-pounds.*		*Pounds per sq. inch.*
1	18	63	0	12.9	0.646	4.16	3.19	.....	.....	.....	.....	.....	.....	.....	This arm used in experimenting on method of test.	7,500
2	23½	35	0	10.7	.397	4.17	3.19	4,190	7,140	1.90	2,650	4.00	10,066	19,608	Tension failure at center and pinhole[2] followed by compression failure at pinholes.	6,290
3	.....	.....	0	.....	.....	4.07	3.11	3,700	7,940	1.50	4,600	4.00	7,590	22,840	Tension failure at center and compression failure at pinholes.	.....
4	23½	37	0	11.8	.410	4.11	3.16	3,450	6,480	1.10	0	1.30	4,200	5,440	Tension and compression failures at pinholes.	6,060
5	15½	55	0	11.9	.592	4.10	3.15	5,100	9,000	1.30	2,350	4.00	7,590	17,240	Splitting at center bolt followed by tension failure between center and pinhole.	8,760
6	15½	30	0	11.4	.477	4.06	3.16	2,175	4,500	1.10	2,150	4.00	3,170	10,420	Cross-grain tension failure, with compression failure at pinholes.	7,320
7	32	31	5	12.0	.506	4.07	3.12	4,200	8,300	1.00	4,900	4.00	4,440	21,580	Splitting at center bolt followed by tension and compression failures at pinhole.	7,860
8	12½	27	0	11.9	.422	4.11	3.15	4,000	8,000	1.55	1,500	4.00	8,160	13,580	Splitting at center bolt followed by tension and compression failures at pinholes.	6,270
9	.....	.....	0	.....	.....	4.16	3.16	5,000	7,900	0.80	4,050	4.00	3,400	17,150	Tension failures at pinhole, splitting at center bolt, and light compression failures at pinholes.	.....
10	.....	.....	0	.....	.....	4.11	3.20	4,650	8,550	1.20	1,500	4.00	6,300	15,980	Splitting at center bolt followed by tension and compression failures at pinholes.	.....
11	20	40	0	12.1	.452	4.05	3.16	4,000	8,050	1.10	2,850	4.00	4,980	13,500	Splitting at center bolt with tension failure at pinhole.	6,600
12	.....	.....	0	.....	.....	4.09	3.15	5,000	5,500	0.70	.....	0.80	2,224	2,460	Tension failure at center (imperfect test).	.....
Average..	20	40	.42	11.5	.479	4.10	3.16	4,050	7,590	1.26	2,655	3.73	5,990	15,730	Pieces 1 and 12 omitted.....	7,080

LONGLEAF PINE—50 PER CENT HEART (SHIPMENT 91).

13			85			4.06	3.15	5,250	10,340	1.40	0	2.00	9,152	15,180	Splitting at center bolt followed by tension and compression failures at pinhole.	
14			65			4.18	3.20	4,475	9,320	1.30	0	2.30	7,212	7,930	Splitting at center bolt; almost complete tension failure at pinhole.	
15	24½	41	60	11.2	0.578	4.09	3.11	4,850	9,860	1.20	0	3.70	7,030	13,780	Splitting at center bolt followed by tension failure at knot and compression failure at pinhole.	8,740
16	20	42	60	13.5	.462	3.95	3.11	3,400	7,700	1.40	1,700	4.00	6,512	11,220	Compression and tension failure at pinhole.	6,640
17	17	44	55	14.0	.587	4.16	3.18	4,300	9,450	1.30	2,300	4.00	7,140	12,920	Tension failure at center and pinhole	7,930
18	*7½*	*45*	*10*	*14.5*	*.534*	*4.03*	*3.17*	*4,025*	*7,750*	*1.10*	*1,700*	*4.00*	*4,772*	*10,360*	Tension failure at knot near center and compression failure at pinhole.	7,960
19	21	48	35	13.1	.560	4.07	3.11	4,975	9,550	1.20	2,750	4.00	6,980	20,360	Splitting at center bolt followed by tension and compression failures at pinholes.	7,990
20	19	46	70	13.5	.595	4.09	3.13	5,650	9,150	1.00	2,650	4.00	5,360	18,000	Splitting at center bolt with tension failure at pinhole.	8,780
21	8	41	5	13.5	.541	4.03	3.17	4,050	8,150	1.10	2,000	4.00	5,010	10,400	Tension failure at pinhole	7,300
22	16	45	60	14.8	.473	4.06	3.21	3,850	8,000	1.19	0	1.19	5,420	5,420	Complete brash tension failure at pinhole.	8,250
23			35			4.08	3.10	4,300	9,700	1.70	2,400	4.00	11,360	22,910	Splitting at center bolt followed by compression and tension failures at pinhole.	
24			*35*			*4.07*	*3.12*	*4,125*	*7,500*	*0.99*	*1,600*	*4.00*	*4,240*	*10,460*	Splitting at center bolt followed by tension failure at knot at pinhole and compression failure at pinhole.	
25	16	43	35	13.2	.485	4.14	3.21	4,000	7,600	1.05	2,800	4.00	4,600	11,100	Splitting at center bolt followed by tension failure at pinhole.	6,940
Average	16½	44	47	13.5	.542	4.08	3.15	4,400	8,775	1.23	1,530	3.48	6,520	13,080		5,425

LONGLEAF PINE—75 PER CENT HEART (SHIPMENT 91).

26			10			4.05	3.16	4,175	9,100	1.40	2,400	4.00	7,730	17,180	**Tension failure at center and compression failure at pinhole.**	
27	8	45	50	13.4	0.623	4.10	3.20	5,250	10,400	1.20	1,950	4.00	7,200	15,780	Tension failure at center and compression and tension failure at pinhole.	8,810
28			50			4.12	3.13	5,075	8,510	1.00	1,850	4.00	4,780	12,060	Tension failure center to pinhole; compression failure at pinhole.	
29	8½	54	25	13.5	.678	4.07	3.11	4,225	8,680	1.00	3,750	4.00	4,580	17,560	Tension failure pinhole to pinhole; compression failure at pinhole.	8,570
30	26	52	50	12.7	.583	4.06	3.18	4,800	9,650	1.20	2,400	4.00	6,860	16,960	Tension and compression failures at pinhole.	8,710
31	26½	50	15	13.5	.611	4.05	3.17	5,450	10,800	1.50	3,200	4.00	10,250	22,200	Compression and tension failures at pinholes.	8,910

[1] Definitions of the terms used to describe the kinds of failure are given in Forest Service Circular 38 (Revised), "Instructions to Engineers of Timber Tests."
[2] Where the words "pinhole" or "pinholes" are used in these descriptions the pinholes 8 inches from the center of the arm are meant.

TABLE 1.—*Detailed summary of tests on cross-arms*—Continued.

LONGLEAF PINE—75 PER CENT HEART (SHIPMENT 91)—Continued.

Piece No.	Rings per inch.	Summer wood.	Sap.	Moisture.	Specific gravity dry.	Bending tests. Arms mounted on stub pole and braced. Loaded at six pinholes.									Maximum fiber stress in compression parallel to grain.
						Height at center.	Width at center.	Load at ¼-inch deflection.	Maximum load.	Deflection at maximum load.	Load at 4-inch deflection.	Total deflection.	Work to maximum load.	Total work.	Kind of failure.	
		Per cent.	*Per cent.*	*Per. cent.*		*Inches.*	*Inches.*	*Pounds.*	*Pounds.*	*Inches.*	*Pounds.*	*Inches.*	*Inch-pounds.*	*Inch-pounds.*		*Pounds per sq. inch.*
32	.....	.....	50	.....	.....	4.20	3.16	5,750	11,250	1.40	1,850	4.00	10,020	21,700	Compression failures at pinholes; splitting at center bolt; tension failure at pinhole.	.....
33	15½	65	10	14.5	.687	4.21	3.07	6,250	12,100	1.30	2,850	4.00	9,740	22,740	Splitting at center bolt; compression and tension failures at pinhole.	10,400
34	27	47	40	13.8	.538	4.13	3.22	4,850	9,950	1.66	0	1.66	10,580	10,580	Slight splitting at center bolt; sudden and complete tension failure at pinhole.	7,580
35	19	58	5	13.0	.671	4.02	3.13	6,600	10,850	1.00	3,650	4.00	6,360	24,140	Split at center bolt; tension failure at pinhole; splitting at center bolt; compression failure at pinhole.	9,680
36	.....	.....	45	.....	.....	3.98	3.16	5,000	10,650	1.20	2,400	4.00	7,400	21,160	Split at center bolt; tension and compression failures at pinhole, with increased split at center bolt.	.....
Average..	18½	53	32	13.5	.627	4.09	3.15	5,220	10,180	1.26	2,390	3.79	7,800	18,370	.....	8,950
LONGLEAF PINE—100 PER CENT HEART (SHIPMENT 91).																
37	12	34	0	12.1	0.504	4.10	3.13	4,150	9,120	1.20	2,450	4.00	6,208	14,620	Splitting at center bolt; tension failure at center; tension and compression failures at pinholes.	7,880
38	.....	.....	0	.....	.....	4.15	3.16	5,150	8,490	1.00	1,450	4.00	5,100	14,510	Splitting at center bolt; tension and compression failures at pinhole.	.....
39	.....	.....	0	.....	.....	4.12	3.16	4,350	9,710	1.30	1,825	4.00	7,260	20,320	Compression failure at pinhole; horizontal shear failure along check; tension and compression failures at pinholes.	.....
40	20	43	0	12.1	.576	4.05	3.11	3,900	8,450	1.10	2,350	4.00	4,980	15,160	Tension failure pinhole to center and center to brace; tension and compression failures at pinholes.	8,500
41	13½	54	0	15.9	.683	4.10	3.10	5,100	11,350	1.60	2,650	4.00	11,800	18,400	Splitting at center bolt; tension failure at center and pinhole; compression failure at pinhole.	9,260
42	15½	48	5	11.3	.583	4.10	3.13	5,050	10,400	1.20	3,250	4.00	7,180	19,540	Tension failure at pinhole; split center to pinhole; tension and compression failures at pinhole.	9,240

43	18	48	0	13.0	.752	4.15	3.05	5,050	10,400	1.70	4,600	4.00	12,280	25,200	Splitting at center bolt; tension and compression failures at pinhole.	10,500
44	12	43	5	12.6	.658	4.05	3.10	5,450	11,000	1.30	4,000	4.00	8,740	21,480	Splitting at center bolt, followed by tension and compression failures at pinhole.	10,200
45	18	34	0	12.3	.565	4.23	3.20	3,850	4,750	0.90	.....	.....	.....	.....	This arm tested with support at center only; failure by brash tension at pinhole.	7,410
46	.....	.....	5	.....	.....	4.15	3.14	4,500	9,350	1.40	3,150	4.00	8,230	17,240	Splitting at center; tension failure at center and pinhole.	.....
47	15½	50	0	12.6	.636	4.15	3.13	5,075	9,550	1.30	3,850	4.00	7,920	18,960	Split at center bolt; tension failure at pinhole; increased split at center bolt, with tension failure at center and compression failure at pinholes.	8,560
48	.....	.....	*0*	.....	.....	*4.00*	*3.16*	*4,150*	*8,250*	*1.05*	*2,500*	*4.00*	*4,660*	*13,780*	Split at center bolt, with tension failure at knot near center, split extending to pinhole.	.....
Average..	15.2	46	1.25	12.8	.627	4.10	3.13	4,720	9,643	1.27	2,920	4.00	7,660	18,110	Piece No. 45 omitted.....	8,940

SHORTLEAF PINE (SHIPMENT 95).

1	17	43	95	.....	.....	4.15	3.19	3,300	6,790	1.10	0	3.50	4,144	7,770	Sudden tension failure at pinhole.....	.....
2	13	43	90	13.3	.587	4.13	3.18	4,850	8,840	1.00	2,500	4.00	5,060	15,020	Tension failure pinhole to center bolt; compression and tension failures at pinhole.	7,950
3	11	38	65	13.6	.597	4.11	3.16	4,950	9,910	1.37	800	4.00	8,400	13,400	Split at center bolt; compression failure at pinhole; tension failure pinhole to center and at opposite pinhole.	8,190
4	.....	.....	75	.....	.....	4.06	3.13	4,900	9,900	2.00	3,150	4.00	14,460	20,950	Tension failure near center; split at center bolt; tension failure to left of center and compression failure at pinhole.	.....
5	7	62	100	12.9	.768	4.11	3.14	4,350	10,000	1.40	3,500	4.00	8,190	16,680	Tension failure pinhole to center, afterwards extending to opposite pinhole.	6,660
6	7	46	90	12.8	.529	4.12	3.18	3,225	9,350	1.50	1,800	4.00	8,060	16,940	Compression failure at pinhole; tension failure pinhole to center.	6,380
7	.....	.....	55	.....	.....	4.15	3.12	5,000	9,850	1.20	3,900	4.00	7,040	25,100	Compression failures at pinholes; tension failure at center.	.....
8	8	31	95	13.2	.479	4.19	3.20	3,550	6,900	1.60	2,300	4.00	7,680	12,540	Tension failure. Arm tested wrong side up by mistake.	5,550
9	8½	60	100	13.8	.630	4.14	3.14	4,200	9,200	1.40	1,700	4.00	7,870	12,620	Tension failure at pinhole.....	8,430
10	10½	40	75	13.8	.460	4.16	3.13	4,800	9,100	1.50	0	3.80	8,980	13,700	Split at center bolt; compression and tension failures at pinhole; complete tension failure at pinhole.	7,240
11	12	49	95	13.1	.580	4.13	3.15	5,300	11,300	1.60	3,300	4.00	11,080	28,480	Compression failures at pinholes; tension failure in central portion of arm.	8,020
12	.....	.....	15	.....	.....	4.05	3.11	5,050	10,000	1.49	1,600	4.00	9,840	14,900	Splitting at center bolt followed by tension failure at center.	.....
Average..	10½	46	79	13.3	.516	4.12	3.15	4,460	9,260	1.43	2,050	3.94	8,400	16,510	.....	7,300

TABLE 1.—*Detailed summary of tests on cross-arms*—Continued.

SHORTLEAF PINE—CREOSOTED (SHIPMENT 106).

Piece No.	Rings per inch.	Summer wood.	Sap.	Moisture.	Specific gravity dry.	Bending tests. Arms mounted on stub pole and braced. Loaded at six pinholes.										Maximum fiber stress in compression parallel to grain.
						Height at center.	Width at center.	Load at ¼-inch deflection.	Maximum load.	Deflection at maximum load.	Load at 4-inch deflection.	Total deflection.	Work to maximum load.	Total work.	Kind of failure.	
		Per cent.	*Per cent.*	*Per cent.*		*Inches.*	*Inches.*	*Pounds.*	*Pounds.*	*Inches.*	*Pounds.*	*Inches.*	*Inch-pounds.*	*Inch-pounds.*		*Pounds per sq. inch.*
1	13	47				4.20	3.20	3,800	7,470	1.20	2,900	4.00	5,484	16,420	Tension failure center to pinhole; increased tension failure; compression failure and increased tension failure at pinhole.	6,340
2						4.16	3.21	3,725	7,900	1.20	2,050	4.00	5,320	14,860	Tension failure center to pinhole; compression failure at pinhole; tension failure at pinhole.	
3						4.20	3.20	4,150	9,120	1.90	3,600	4.00	12,320	26,120	Tension failure at center with compression failure at pinholes.	
4						*4.15*	*3.19*	*4,150*	*7,740*	*1.10*	*2,550*	*4.00*	*4,800*	*11,720*	Sudden failure tension at pinhole	
5	*14*	*54*				*4.12*	*3.18*	*4,200*	*6,750*	*0.80*	*3,000*	*4.00*	*2,860*	*17,140*	Cross-grain tension failure center to pinhole; compression failure at pinhole; increase of first failure.	5,470
6	13	40				4.19	3.18	4,875	8,100	1.00	2,500	4.00	4,760	14,640	Splitting at center bolt; tension failure center to pinhole; increased tension failure with compression failure at pinhole.	7,060
7						*4.20*	*3.18*	*3,425*	*8,650*	*1.40*	*1,900*	*4.00*	*6,720*	*9,880*	Sudden tension failure at pinhole	
8	6	50				4.23	3.15	3,650	8,500	1.30	0	1.30	6,140	6,140	Very brash complete tension failure at pinhole.	5,570
9	10	48				*4.16*	*3.17*	*4,800*	*7,900*	*0.90*	*4,350*	*4.00*	*3,780*	*16,980*	Cross-grain tension failure, extending from pinhole and passing below center bolt.	5,940
10	12	37				4.15	3.21	2,800	4,700	0.95	0	3.13	2,630	4,330	Tension failure at pinhole	5,210
11	14	47				4.20	3.20	3,550	5,500	0.79	0	3.70	2,260	8,290	Splitting at center bolt; brash tension failure at pinhole.	5,190
12	9½	75				4.15	3.17	4,175	9,900	1.60	3,450	4.00	9,760	23,800	Tension failure at center; compression failure at pinhole; tension failure center to pinhole; increased tension and compression failures at pinhole.	5,300
Average	11½	50				4.17	3.18	3,940	7,690	1.18	2,190	3.68	5,570	13,360		5,770

WHITE CEDAR (SHIPMENT 99).

1			0			4.23	3.16	2,525	6,000	1.30	1,900	4.00	4,622	8,820	Sudden tension failure at pinhole	
2	12	65	0	15	.368	4.25	3.16	2,850	5,240	0.90	0	3.80	2,526	8,172	Brash tension failure at pinhole; compression failure at pinhole; increased tension failure at pinhole.	4,780
3	12	45	3	14.7	.388	4.25	3.13	3,900	6,930	1.40	0	3.10	6,020	9,520	Sudden tension failure just inside pinhole; compression and further tension at point of first failure.	5,060
4	20½	43	0	14.9	.386	4.25	3.19	2,950	3,950	0.80	0	3.00	1,620	4,430	Nearly complete tension failure at pinhole, continuing until arm broke in two.	4,580
5	12	60	3	16.7	.413	4.25	3.24	3,050	7,450	1.60	0	3.00	7,440	8,860	Splitting at center bolt; compression failure at pinhole; split at center; tension failure at pinhole; complete tension failure.	5,490
6	9½	31	5	13.4	.351	4.19	3.16	2,600	4,700	0.90	1,550	4.00	2,240	5,820	Brash tension failure at pinhole	4,550
7	7	40	0	14.1	.292	4.25	3.16	1,625	3,850	1.10	0	3.10	2,250	2,940	Sudden failure by brash tension at pinhole.	3,520
8			0			4.24	3.20	3,650	6,850	1.00	1,450	4.00	3,700	11,870	Compression and tension failures at pinholes.	
9	10	38	5	13.3	.337	4.23	3.21	2,525	3,400	0.70	0	2.30	1,400	1,700	Splitting at center bolt, followed by very brash complete tension failure at pinhole.	4,510
10			2			4.25	3.19	2,800	5,050	0.85	1,300	4.00	2,180	7,320	Sudden tension failure at pinhole	
11	13	35	0	12.1	.381	4.20	3.16	3,000	3,950	0.62	0	2.80	1,280	4,180	Successive brash tension failures. Arm badly checked before test.	5,110
12			0			4.18	3.21	2,900	5,050	0.90	2,200	4.00	2,500	9,540	Compression failure at pinhole; slightly cross-grain tension failure pinhole to center; increased compression failure.	
Average	12	45	1.50	14.3	.364	4.23	3.18	2,860	5,200	1.01	700	3.42	3,150	6,930		4,700

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HENRY S. GRAVES, Forester.

FOREST FIRE PROTECTION UNDER THE WEEKS LAW IN COOPERATION WITH STATES.

BY

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1912.

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FOREST FIRE PROTECTION UNDER THE WEEKS LAW IN COOPERATION WITH STATES.

FOREST FIRE PREVENTION AND CONTROL.

One year's operation of Weeks law completed.

The forest fire season of 1911 marked the first year's operation of section 2 of the Weeks law. This section authorizes the Secretary of Agriculture to cooperate with States in protecting from fire the forested watersheds of navigable streams.

Federal, State, and private protection.

The importance of protection from forest fires is shown by the efforts being made to bring it about. The Forest Service is charged with the protection of 162 National Forests, aggregating nearly 200,000,000 acres. Fifteen States have effective forest fire laws enforced by efficient organizations under a State forester or a chief fire warden; nine others have made a start in this direction. Private owners in the Northeast and the Northwest have organized protective associations, each member of which is assessed for expenses according to the acreage of his holdings. Individual owners over the entire country are more and more realizing that not only is it practicable to protect their timber, but profitable also, because of its constantly increasing value. The joint efforts of all these agencies are reducing the fire risk and making the task of each easier.

Losses by forest fires.

It has been estimated that an average of 10,000,000 acres is burned over annually in the United States, with a money loss of about $20,000,000. The loss in some States is enormous. In Wisconsin, during the three years prior to 1911, the losses were as follows:

Year.	Acres burned.	Total loss.
1908	1,209,432	$9,194,379
1909	166,000	104,000
1910	892,000	5,000,000

Minnesota had in 1910 a loss estimated by the forest commissioner at more than 1,000,000 acres burned and nearly $2,000,000 damage; Oregon lost in the same year, according to the State forester, nearly 2,000,000,000 feet of timber, with a value of about $2,500,000.

Forest fires generally have been regarded with indifference or as unavoidable. Too often life is lost and valuable property destroyed before the public is aroused to the danger.

Destruction of mature and young growth robs the present and the future.

In the coniferous forests of the North the destruction of merchantable timber over vast areas is frequent. In the pine or hardwood forests of the South the chief damage is the repeated killing of young growth, especially on cut-over lands. Such damage, unlike the destruction of the Northern forests, is not as strikingly apparent but the loss is, nevertheless, a severe one, because the young growth

has a very great future value, and upon it depends the permanency of the lumber industry in the region.

Fire destroys also the soil covering; this causes rapid run-off on steep slopes, and erosion results. The soil thus washed out is the chief source of sediment in the channels of navigable streams. Forest fires, therefore, cause irregularity of streamflow and loss of navigability. This calls for active assistance from the Federal Government. Section 2 of the Weeks law is designed to authorize this assistance.

Streamflow is disturbed and navigation impeded.

THE WEEKS LAW, SECTION 2.

The purpose of section 2 of the Weeks law is to protect navigable streams, through promoting forest protection by the States and by private owners. The appropriation for the purpose is $200,000, which is available until expended. The law requires that (1) the protection must be confined to the forested watersheds of navigable streams; (2) the State must have provided by law for a system of forest fire protection; and (3) the Federal expenditure in any State must not exceed in any Federal fiscal year the amount appropriated by the State for the same purpose.

Purpose of the law.

Its requirements.

ADMINISTRATION OF THE LAW.

The law is administered by the Forest Service under an agreement between the Secretary of Agriculture and the State.

In the administration of this act, the Forest Service places a broad interpretation on what constitutes a navigable stream, with the exception that streams used only for floating logs, canoes, or rowboats will not be considered navigable. As a general basis for decisions on the question of navigability the reports of the Chief of Engineers, United States Army, are used.

No State will receive more than $10,000 in any one year. Nor should it be assumed that the Federal Government will duplicate within the limit any appropriation made by a State for fire protection. It is proposed to disperse the Federal fund as widely as possible, and throughout three years, in order that the educational value of the work may be fully realized. A fund of about $20,000 has been reserved to increase allotments to States where an emergency due to unusual drought may occur. The expenditures in 1911 were about $39,000. The allotments for 1912 will be about $70,000.

Policy as to use of the fund.

In making the allotments consideration is given especially to the possibility of active assistance from private owners; to the amount of appropriation from each State; to the importance of the watersheds to be protected with respect to streamflow and navigation; to the relative area of the watersheds; to the kind and value of the forests; and to the relative fire risk. The States assisted must at least have initiated efficient fire protective organizations.

Considerations determining allotments.

They must secure the cooperation of private owners in various activities, such as the hire of patrolmen, purchase of fire-fighting equipment, and the construction of lookout stations and telephone lines. The Forest Service takes the ground that before a region shall receive Federal

Cooperation of private owners required.

aid the private owners must make a reasonable effort themselves. This requirement is most satisfactorily met by protective associations of timberland owners such as those in Maine, New Hampshire, and Oregon.

State appropriations.

The aim is to assist each State as far as possible, helping especially the ones which have difficulty in providing efficient protection. The State which can make only a small appropriation may receive an amount equal to the sum which it appropriates; while the State whose appropriation is relatively large and which can of itself provide safe protection may receive a relatively small allotment.

Other things being equal, the more important watershed, or the larger area, or the more valuable forest, receives the larger allotment for protection, full weight being given in each case to the relative fire hazard.

Unexpended balances not lost to States.

Any unexpended balance from a State's allotment at the end of the calendar year, when the cooperative agreements between the States and the Secretary of Agriculture expire, will be available for expenditure by the State under a renewal of the agreement during the next calendar year. Thus the State will never lose an unexpended balance and can always count upon this balance, at least, as the minimum allotment for the ensuing calendar year.

TERMS OF THE COOPERATIVE AGREEMENT.

The standard form of cooperative agreement is given in full in an appendix to this publication. A specific agreement is made with each State with such variations in detail as local conditions require.

Fire plans and maps.

The State supplies the Forest Service with a comprehensive fire plan, which includes maps showing the areas to be protected, the headquarters and approximate routes of patrolmen, and all features necessary to a clear understanding of the State's plan of fire control. The appendix contains a map which forms part of the fire plan for northern New Hampshire.

Federal funds for salaries only.

Except for a nominal salary to the State forester, the expenditures made by the Federal Government are exclusively for the salaries of Federal patrolmen, including men assigned to lookouts, to railroad patrol, and to similar duties. The distinction between the Federal and the State patrolmen is advisable in order to simplify both the fiscal operation of the agreement and the inspection of the use of the funds.

Work when patrol is unnecessary.

During wet periods, when patrol is unnecessary, the men are employed on other protective work, such as trail clearing, road making, and telephone construction. The State's expenditures that are to offset those of the Federal Government may properly include, however, any expenditures for protecting forested watersheds of navigable streams from fire. These may be for the construction of lookout stations or other protective improvements and proportionate amounts of supervisory expenses.

State officer given Federal appointment.

The State forester or the officer of similar rank and duties is given a Forest Service appointment at a nominal salary, and he may employ Federal patrolmen and certify to their services on Government vouchers. These are submitted for payment each month and must be accompanied by dupli-

cates of State vouchers to show the expenditures made by the State to offset those of the Federal Government; and an individual pay check is sent directly to each Federal patrolman. The State officer is given as much authority and latitude as possible in the expenditure of Federal funds. He is placed in practically the same position as a National Forest supervisor, by being allowed a wide degree of discretion and by being held fully accountable for results. He selects the Federal patrolmen, instructs them in their duties, and supervises their work.

Federal patrolmen given police powers by the State.

The Federal patrolmen must be given such police powers for the prevention and control of forest fires as the laws of the State provide, they must be authorized to employ assistance in fighting fires, and they must be equipped with fire-fighting tools.

Federal inspection of work.

The Forest Service inspects the cooperative work on the protected areas. This is essential, since it serves to determine the efficiency of the plan of fire control and the effectiveness of the work done. Also it enables the Service both to give and to receive practical suggestions on the ground. The Service may, for cause, withdraw its approval of the expenditure of Federal funds on any area or terminate the Federal appointment of the State officer or of any Federal patrolman.

WORK DONE IN 1911.

The States which received Federal aid under the Weeks law in 1911 and the amounts expended by them and by the Government are shown in the following summary:

State.	State expenditures.[1]	Federal expenditures.	Allotment to States.	Unexpended—	
				Balance of allotment.	Balance of $200,000 fund Jan. 1, 1912.
Maine	$23,557.07	$9,991.80	$10,000	$8.20	.....
New Hampshire	13,876.21	6,219.50	7,200	980.50	.....
Vermont	2,243.90	1,218.00	2,000	782.00	.....
Massachusetts	400.12	365.00	1,800	1,435.00	.....
Connecticut	513.96	6.00	1,000	994.00	.....
New York	3,837.59	2,000.00	2,000	.....	.....
New Jersey	1,241.51	990.00	1,000	10.00	.....
Maryland	262.85	261.00	600	339.00	.....
Wisconsin	20,841.87	4,437.25	5,000	562.75	.....
Minnesota	25,675.77	10,000.00	10,000	.....	.....
Oregon	8,758.89	3,305.00	5,000	1,695.00	.....
Total	101,209.74	38,793.55	45,600	6,806.45	$161,206.45

[1] As shown on State vouchers or statements forwarded with Federal vouchers. These are not necessarily the total State expenditures.

Watersheds protected.

Federal funds are rarely expended over an entire watershed, but only on those portions which have most protective value, or which are most liable to fire damage. The watersheds which received cooperative protection were the following:

Maine.....Narraguagus, Union, Penobscot, and Kennebec.
New Hampshire.....Androscoggin, Saco, Connecticut, and Merrimac.
Vermont.....Connecticut, Otter Creek, and Hudson.
Massachusetts.....Nashua, Thames, Connecticut, Housatonic, and Hudson.
Connecticut.....Thames, Connecticut, and Housatonic.

New York.....Hudson and Delaware.
New Jersey.....Hackensack, Passaic, Delaware, and Raritan.
Maryland.....Potomac and Youghiogheny.
Wisconsin.....Chippewa and Wisconsin (headwaters of the Mississippi).
Minnesota.....St. Louis, Rainy, Mississippi, and Red River of the North.
Oregon.....Columbia, Willamette, Nehalem, Wilson, Siletz, Umpqua, Coos, Rogue, and Klamath.

Five hundred and nine Federal patrolmen were employed, of whom about 200 were on continuous pay from the date of appointment to the end of the season. They received from $2 to $2.50 a day. When not directly under the State forester, or warden, they were assigned to district wardens or rangers who supervised and inspected their work. The patrolmen are usually given specific written instructions as to routes of travel and other duties.

Number of Federal patrolmen.

Supervision of patrol.

Each had a district to guard varying in area from about 25,000 to 100,000 acres. Without necessarily attempting to cover the whole district he made his rounds of the dangerous places on the most valuable areas at the most advantageous times. These routes varied from 10 to 40 miles a day, depending on the most feasible method of travel, usually by foot, horseback, or bicycle. Along the railroad lines, except where oil-burning locomotives were used, there was a special and constant patrol, in some places on foot and in others on railroad velocipedes or speeders.

Area covered by patrol.

The patrolman carries a map of his district and adjoining districts showing the major topographic features and the approximate location of the Federal and State patrol routes, patrolman's and fire warden's headquarters, telephone lines, lookout stations, roads, trails, and tool-supply boxes, or any features which might aid him in an emergency. He also must carry some fire-fighting tool, such as a shovel or a collapsible canvas pail.

Equipment of patrolman.

The most important duties of the patrolman are putting out small fires, warning persons against setting or leaving fires, and recording their names when advisable. In the larger fires he has authority under the State law to call out help.

Duties of patrolman.

In addition to regular patrol duty and fire fighting, his work includes watching for fires from lookout stations, burning slash, and constructing protective improvements.

In most of the mountainous regions, especially in the Northeast, the lookout station is a highly developed feature of the State's fire protective system. It furnishes the primary control of the fire situation, while the patrol conducted in the valleys beneath forms the secondary control. The station is generally permanent, and consists of a lookout cabin or tower on top of a mountain, possibly with living quarters farther down where water can be had. The station is connected by telephone with the country below and with other lookouts, and equipped with field glasses, a map of practicable size, plane table, and alidade. Usually the watchman lives on the mountain, and during clear days is continuously on duty. In rainy or thick weather, when watching is not necessary or feasible, he is busy inspecting or repairing the telephone

Lookout stations for primary control.

Telephone connections.

line or keeping clear the trail, by which the line can be traveled quickly and damage to it located promptly. The watchman is supplied with a list of the names and telephone-call numbers of chief wardens, deputy wardens, patrolmen, watchmen, timberland owners, lumbermen, and all persons who may render help in the territory covered by the lookout; and he notifies the proper persons when he discovers a fire. From the mountain top he is generally able promptly to discover fires which might otherwise burn for hours and, perhaps, gather tremendous headway before they would have been detected from the lower valleys.

The practical value of the lookout station has been thoroughly tested; it is one of the best assets of a timbered country. Wherever possible the Federal Government prefers that its funds be expended for the salaries of lookout watchmen.

Protective improvements constructed.

When there was no need for patrolling the men were employed in the construction of protective improvements. In some States a great deal of work of this kind was accomplished last year. An example of what may be done was furnished by Wisconsin.

There was practically no danger from forest fires on the cooperative area in Wisconsin after the middle of July. It would have been unwise to dismiss the patrolmen, since there was no telling when dry weather might come, and it would have been difficult to get hold of the same men again or others quite as competent. The improvement work, therefore, was pushed ahead rapidly to make the area more traversable and thus easier to protect. Nearly half of the area is State land included in the State forest reserve. The plan was to divide the more valuable portions, and those of greatest fire risk, into blocks of about 40 acres by constructing roads and fire lines so that the patrol force would have a reasonably good chance of holding a fire within the block in which it started.

Firebreaks constructed in Wisconsin.

The roads will be about 3 miles apart, and from them fire lines will extend to such natural fire barriers as lakes, rivers, and wet swamps. For the most part, the roads were built by removing the ties from old logging railroad grades and then leveling the grades with plow and drag. This network of old grades throughout a large portion of the cooperative area made road construction comparatively inexpensive. Where the roads will become main thoroughfares care was taken to build them for permanent use. Less expensive fire lines and trails seemed sufficient where fire protection was the only reason for their construction. There were constructed during 1911 by the State and Federal patrolmen, with temporary help, over 110 miles of road and 87 miles of fire line.

Telephone lines built.

A complete telephone system was planned and 24½ miles of line were constructed. Three lines radiating from a headquarters camp connect it with distant and important ranger stations. These lines will be extended during the summer of 1912 to various other points of vantage, such as lookout towers, ranger cabins, and summer resorts.

Other important protective measures were the "brushing out" of trails; the cutting of old stubs, chiefly birch, for a distance of 6 rods on each side of 69 miles of roads and fire lines; and the burning of dangerous slashings on 1,200 acres.

The cost of this work in Wisconsin was a little over $11,000.

RESULTS ACCOMPLISHED.

There were many practical results of cooperation under the Weeks law. Hundreds of fires left by campers, fishermen, and hunters, or set by careless smokers and by locomotives, were discovered by the patrolmen and promptly extinguished. Great progress was made on permanent improvements that will simplify future fire control and prevention. But in addition to these tangible results, which have been apparent from the start, the educational value of the work although not measurable has been far reaching. Except in a few States, last year was the first when any systematic State patrol of the forests was conducted. It marked the general extension of the State organization cooperating with the Federal Government, in getting out among the people; in educating them, through the actual work done, of the need and value of fire protection; and in encouraging their cooperation.

The public is educated.

The most effective work of the patrolmen was in warning persons met in the woods of the danger of setting fires, and informing them of the fire laws. The patrolmen were generally instructed to record the names and addresses of fishermen, hunters, and campers whenever possible and to send them to the district chief. In New Hampshire 4,200 warnings of this sort were given; more than half the names were recorded, and are now on file in the office of the State forestry commission. Before the next fire season a copy of the fire laws will be sent to each of these persons.

Warnings given.

Sportsmen, loggers, and others who travel the woods are taking greater care in the use of fire; quicker notifications of fire are given to the proper State officer, while before they at best were desultory. Many private owners who were skeptical at the start later saw the practical value of the work and began cooperating in it and contributing toward it. The increased interest of the public was shown by the widespread demand for information on fire protection received by the various State foresters and by the Federal Forest Service.

Greater care by public.

The first direct result of the Weeks law in encouraging State legislation was the passage by the Connecticut Assembly of the following act:

State legislation encouraged.

CHAPTER 292.

AN ACT CONCERNING PREVENTION OF FOREST FIRES.

Be it enacted by the Senate and House of Representatives in General Assembly convened:

SECTION 1. The state forest fire warden may take such action as he may deem necessary to provide for the prevention and control of forest fires in groups of towns, and is hereby authorized to enter into an agreement with the secretary of agriculture of the United States, under authority of the act of congress of March 1, 1911, for the protection of the forested watersheds of navigable streams in this state. Said state forest fire warden may appoint patrolmen, who shall receive not more than twenty-five cents per hour for time actually employed, and may establish and equip fire lookout stations and furnish necessary equipment for such patrolmen.

SECTION 2. Any patrolman appointed for such purpose by said state forest fire warden may arrest, without warrant, any person taken by him in the act of violating any of the laws of this state for the protection of forest and timber lands.

SECTION 3. The disbursements of the state forest fire warden in carrying out the purposes of this act shall be paid by the state from the appropriation for fire wardens.

SECTION 4. This act shall take effect from its passage.

Approved, September 26, 1911.

Practical results in saving property.

The first question that naturally occurs to one looking for measurable results is how far the expenditures succeeded in preventing fire losses. Maine and New Hampshire furnish striking examples of comparative losses in 1903 and 1911, two of the most dangerous fire years on record in these States. The comparison is based only on the watersheds where cooperative fire protection between the Federal Government and the State and timberland owners was established last year.

Year.	Season of drought.	Maine.		New Hampshire.	
		Acres burned.	Damage.	Acres burned.	Damage.
1903	Apr. 17 to June 6	172,040	$679,423	84,255	$200,000
1911	Apr. 16 to June 1, June 20 to July 17	91,471	154,284	10,925	34,036

While the danger season of 1911 was longer and generally considered to be the more severe, the area burned over and the amount of damage were considerably less than in 1903, and the decrease without doubt can be attributed in great measure to the protection afforded in 1911, as compared with the almost utter lack of it, except by a few private owners, in 1903.

EXTENDING COOPERATIVE PROTECTION.

The Federal Government desires to extend this cooperative protection to other States. To secure its benefits they must enact a forest-fire law and must appropriate funds for administering it. Few more effective steps could be taken by many States toward the conservation of resources which support important industries than to inaugurate systematic fire protection. The fact that the immediate financial interests of timber owners make them backward in undertaking this insurance of their industry is an additional reason for the States to take the lead. The readiness of the Federal Government to cooperate with the States, under the terms of the Weeks law, as soon as the State makes a start, is an incentive to immediate action.

The States should take the lead.

A State forest fire law should provide, in addition to an organization to fight fires, a patrol force for fire prevention. A general defect in fire laws is that they provide only for fighting fires and not for patrol. The law should, of course, carry an adequate appropriation; the most serious defect has been the inadequacy of appropriation. To protect the National Forests costs about 2 cents an acre annually; the Biltmore tract in North Carolina, about 5 cents an acre; and the lands of the various timber-land protective associations in the Northeastern and Northwestern States, from 2 to 4 cents an acre. It is probable that the State can secure efficient protection for 1 cent an acre, if the larger private owners will assist by contributing toward the protection of their own lands. If, for example, a State contains 5,000,000 acres of forest land which needs protection, an annual expenditure of $50,000 should be sufficient to handle the work effectively. It is improbable that a State would appropriate this amount at the beginning; an appropriation of $10,000 or even less would be sufficient to start the work and demonstrate its value.

What a fire law should provide.

Cost of protection.

APPENDIX.

FORM OF AGREEMENT.

The form of agreement between the Secretary of Agriculture and the State for the protection from fire of the forested watersheds of navigable streams is as follows:

UNITED STATES DEPARTMENT OF AGRICULTURE.

Agreement for the protection from fire of the forested watersheds of navigable streams under section 2, act of March 1, 1911 (36 Stat., 691).

This agreement, made by and between the Secretary of Agriculture of the United States, under authority of section 2 of the act of Congress approved March 1, 1911 (36 Stat., 691), and the State of ..... by and through its State Forestry Commission, witnesseth:

That whereas, the said State has requested the cooperation of the said Secretary in the protection from fire of the forested watersheds of navigable streams; and

Whereas, the said State has provided by law for a system of forest-fire protection;

Now, therefore, the said parties do mutually promise and agree with each other as follows:

1. To establish and maintain a cooperative fire protective system covering any or all private or State forest lands within the State of ..... and situated upon the watersheds of navigable rivers; and to furnish for this purpose Federal and State patrolmen or to take such other protective measures as may be deemed advisable, under the conditions hereinafter provided.

2. The State commission shall furnish maps showing the watersheds and areas which are proposed to be protected under this agreement. The cooperation shall be limited to such watersheds and areas in so far as they shall be approved by the Secretary. The said commission shall indicate the periods during which protection from forest fires is proposed under this agreement; the number of patrolmen, with their stations, which will be employed by the State; the character and extent of other protective measures which it is proposed to put into effect at the expense of the State; and the localities in which it is desired to place Federal patrolmen furnished by the Forest Service.

3. The State commission shall secure for the Federal patrolmen furnished under this agreement, by appointment as deputy State fire wardens or otherwise, without additional compensation, such police powers for the prevention and control of forest fires as may be granted under the laws of the State of ....., and shall equip such Federal patrolmen with such fire-fighting tools or devices and shall authorize them to employ such assistance in fighting fires as its funds and the State fire laws and regulations will permit.

4. The State forester of....., acting as an employee of the State commission, shall be appointed collaborator in the Forest Service of the United States Department of Agriculture at a salary of one dollar ($1) a month, and acting in such capacity shall have direct charge of the force of Federal patrolmen employed under this agreement. The State forester shall select the Federal patrolmen, subject to approval by the Secretary, instruct them *in writing* as to their duties, supervise their work, and certify to their services on pay rolls of the Forest Service.

5. The Federal patrolmen so selected shall be appointed as temporary laborers in the Forest Service at a per diem rate not exceeding.....dollars ($....); provided that they shall be employed exclusively in the protection of areas on the watersheds of navigable rivers which shall have been approved by the said Secretary.

6. The total sum to be expended by the Federal Government during the term of this agreement for the purposes of this agreement may equal but shall not exceed .....dollars ($....); but in no case shall the amount expended by the Federal Government in any Federal fiscal year exceed the amount appropriated by the said State for and expended by it during the same period for the purpose of protecting from fire forested watersheds of navigable streams in said State.

7. Payment for the services of Federal patrolmen employed under this agreement shall be made at the end of each calendar or fractional month on vouchers certified by the State forester as collaborator, and forwarded to the Forester, Forest Service, Washington, D. C., provided that no patrolman will be employed except during the real danger season from forest fires on the watersheds and areas approved by the Secretary under this agreement.

8. The said Secretary and his authorized representative shall have full authority to inspect the protective areas and the force herein authorized, and at his option, by giving the State commission written notice, may withdraw his approval of any such area or portion thereof, or terminate the employment of any Federal patrolman or patrolmen or of the State forester as collaborator in the Forest Service.

9. The State forester shall be responsible for seeing that each patrolman keeps a vigilant lookout for forest fires in or threatening his district, and that he makes every possible effort to extinguish such fires as occur whether they are on lands belonging to the State, the Federal Government, or a private owner, provided that during the patrol period when in the judgment of the State forester patrol is unnecessary the patrolmen may be used on other fire-protection work. The State forester or his representative shall from time to time make such personal inspection of the cooperative fire-protection work done under this agreement as may be necessary to promote the effectiveness of said work.

10. The said State forester shall, with respect to all private forest land afforded protection against fire under this agreement, use every proper means to bring about the active cooperation of the owner in such protection, including aid from him in the form of hire of one or more patrolmen, construction of permanent improvements, and the like.

11. Both the State commission and the Forest Service of the United States Department of Agriculture shall have equal right to publish the results of the cooperation under this agreement: *Provided*, That any results intended for publication, except press notices of momentary or local interest, be approved by the commission and by the Secretary. In all such publications it shall be plainly stated that the results were secured through cooperation between the commission and the Secretary.

12. This agreement shall terminate on the thirty-first (31st) day of December, 1912: *Provided, however*, That it may be renewed, and be in force thereafter, from year to year, by mutual consent of the parties hereto, expressed in writing.

In witness whereof the said commission has hereunto caused its name and seal to be affixed by its proper officers, on the ..... day of ....., 1912, and the said Secretary has hereunto set his hand and affixed his official seal on the date below written.

....
President, State Forestry Commission.

....
Secretary of Agriculture.

Signed and sealed by the Secretary of Agriculture this .... day of ....., 1912.

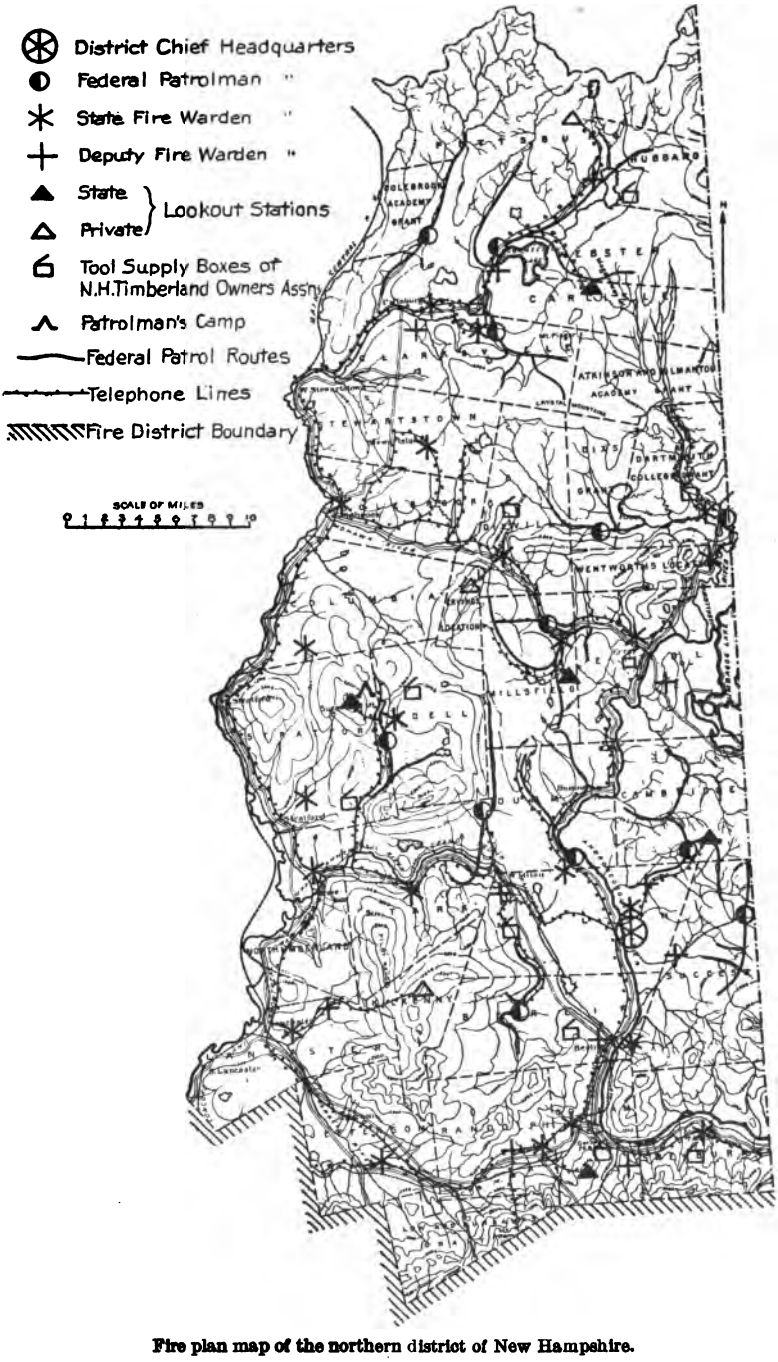
FIRE PLAN MAP.

The accompanying map of the northern district of New Hampshire, including a portion of the cooperative watersheds, is an example of the kind which should accompany a fire protection plan. The map shows, in addition to the headquarters of members of the fire force, the routes of patrolmen and the location of lookout stations, telephone lines, and tool supply boxes.

This district has an area of approximately 1,000,000 acres. It is supervised by a district chief, under whom are patrolmen, lookout watchmen, and fire wardens. In this district in 1911 the expenditures for fire protection were as follows:

State	$6,500
New Hampshire Timberland Owners Association	4,800
Federal Government	3,300
Total	14,600

At $14,600 for the protection of 1,000,000 acres, the rate is less than 1½ cents per acre.



Fire plan map of the northern district of New Hampshire.

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U. S. DEPARTMENT OF AGRICULTURE,

FOREST SERVICE—CIRCULAR 205 (First revision).

HENRY S. GRAVES, Forester.

FOREST FIRE PROTECTION UNDER THE WEEKS LAW IN COOPERATION WITH STATES.

BY

J. GIRVIN PETERS,
CHIEF OF STATE COOPERATION.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1913.

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FOREST FIRE PROTECTION UNDER THE WEEKS LAW IN COOPERATION WITH STATES.

FOREST FIRE PREVENTION AND CONTROL.

Two years' operation of Weeks law completed.

The forest-fire season of 1912 marked the second year's operation of section 2 of the Weeks law. This section authorizes the Secretary of Agriculture to cooperate with States in protecting from fire the forested watersheds of navigable streams.

Federal, State, and private protection.

The importance of protection from forest fires is shown by the efforts being made to bring it about. The Forest Service is charged with the protection of 163 National Forests, aggregating nearly 200,000,000 acres. Eighteen States have effective forest-fire laws, enforced by efficient organizations under a State forester or a chief fire warden; seven others have made a start in this direction. Private owners in the Northeast and the Northwest have organized protective associations, each member of which is assessed for expenses according to the acreage of his holdings. Individual owners over the entire country are more and more realizing that not only is it practicable to protect their timber, but profitable also, because of its constantly increasing value. The joint efforts of all these agencies are reducing the fire risk and making the task of each easier.

Losses by forest fires.

It has been estimated that an average of 10,000,000 acres is burned over annually in the United States, with a money loss of about $25,000,000. The loss in some States is enormous. In Wisconsin, during the three years prior to 1911, the losses were as follows:

Year.	Acres burned.	Value of merchantable standing timber destroyed.	Total loss of all forest products, including merchantable standing timber, young trees, and pulp wood, bark, logs, and similar products.
1908	1,209,000	$2,997,000	$9,194,000
1909	166,000	22,000	104,000
1910	892,000	997,000	5,000,000

Minnesota had in 1910 a loss estimated by the forest commissioner at more than 1,000,000 acres burned and nearly $2,000,000 damage; Oregon lost in the same year, according to the State forester, nearly 2,000,000,000 feet of timber, with a value of about $2,500,000.

Forest fires generally have been regarded with indifference or as unavoidable. Too often life is lost and valuable property destroyed before the public is aroused to the danger.

Destruction of mature and young growth robs the present and the future.

In the coniferous forests of the North the destruction of merchantable timber over vast areas is frequent. In the pine or hardwood forests of the South the chief damage is the repeated killing of young growth, especially on cut-over lands. Such damage, unlike the destruction of the northern forests, is not as strikingly apparent, but the loss is, nevertheless, a severe one, because the young growth has a very great future value, and upon it depends the permanency of the lumber industry in the region.

Streamflow is disturbed and navigation impeded.

Fire destroys also the soil covering; this causes rapid run-off on steep slopes, and erosion results. The soil thus washed out is the chief source of sediment in the channels of navigable streams. Forest fires, therefore, cause irregularity of streamflow and loss of navigability. This calls for active assistance from the Federal Government. Section 2 of the Weeks law is designed to authorize this assistance.

THE WEEKS LAW, SECTION 2.

Purpose of the law.

The purpose of section 2 of the Weeks law is to protect navigable streams, through promoting forest protection by the States and by private owners. The appropriation for the purpose is $200,000, which is available until expended. The law requires that (1) the protection must be confined to the forested watersheds of navigable streams;

Its requirements.

(2) the State must have provided by law for a system of forest fire protection; and (3) the Federal expenditure in any State must not exceed in any Federal fiscal year the amount appropriated by the State for the same purpose.

ADMINISTRATION OF THE LAW.

The law is administered by the Forest Service under an agreement between the Secretary of Agriculture and the State.

In the administration of this act the Forest Service places a broad interpretation on what constitutes a navigable stream, with the exception that streams used only for floating logs, canoes, or rowboats will not be considered navigable. As a general basis for decisions on the question of navigability the reports of the Chief of Engineers, United States Army, are used.

Policy as to use of the fund.

No State will receive more than $10,000 in any one year. Nor should it be assumed that the Federal Government will duplicate within the limit any appropriation made by a State for fire protection. It is proposed to disperse the Federal fund as widely as possible, and throughout three years, in order that the educational value of the work may be fully realized. A fund of about $20,000 has been reserved to increase allotments to States where an emergency due to unusual drought may occur. The expenditures in 1912 were about $50,000. The allotments for 1913 will be about $90,000.

In making the allotments consideration is given especially to the possibility of active assistance from private owners; to the amount of appropriation from each State; to the importance of the watersheds to be protected with respect to stream flow and navigation; to the relative area of the watersheds; to the kind and value of the forests; and to the relative fire risk. The States assisted must at least have initiated efficient fire protective organizations.

Considerations determining allotments.

They must secure the cooperation of private owners in various activities, such as the hire of patrolmen, purchase of fire-fighting equipment, and the construction of lookout stations and telephone lines. The Forest Service takes the ground that before a region shall receive Federal aid the private owners must make a reasonable effort themselves. This requirement is most satisfactorily met by protective associations of timberland owners such as those in Maine, New Hampshire, Washington, and Oregon.

Cooperation of private owners required.

The aim is to assist each State as far as possible, helping especially the ones which have difficulty in providing efficient protection. The State which can make only a small appropriation may receive an amount equal to the sum which it appropriates; while the State whose appropriation is relatively large and which can of itself provide safe protection may receive a relatively small allotment.

State appropriations.

Other things being equal, the more important watershed, or the larger area, or the more valuable forest, receives the larger allotment for protection, full weight being given in each case to the relative fire hazard.

TERMS OF THE COOPERATIVE AGREEMENT.

The standard form of cooperative agreement is given in full in an appendix to this publication. A specific agreement is made with each State with such variations in detail as local conditions require.

The State supplies the Forest Service with a comprehensive fire plan, which includes maps showing the areas to be protected, the headquarters and approximate routes of patrolmen, and all features necessary to a clear understanding of the State's plan of fire control. The appendix contains a map which forms part of the fire plan for northern New Hampshire.

Fire plans and maps.

Except for a nominal salary to the State forester, the expenditures made by the Federal Government are exclusively for the salaries of Federal patrolmen, including men assigned to lookouts, to railroad patrol, and to similar duties. The distinction between the Federal and the State patrolmen is advisable in order to simplify both the fiscal operation of the agreement and the inspection of the use of the funds. During wet periods, when patrol is unnecessary, the men are employed on other protective work, such as trail clearing, road making, and telephone construction. The State's expenditures that are to offset those of the Federal Government may properly include, however, any expenditures for protect-

Federal funds for salaries only.

Work when patrol is unnecessary.

ing forested watersheds of navigable streams from fire. These may be for the construction of lookout stations or other protective improvements and proportionate amounts of supervisory expenses.

State officer given Federal appointment.

The State forester or the officer of similar rank and duties is given a Forest Service appointment at a nominal salary, and he may employ Federal patrolmen and certify to their services on Government vouchers. These are submitted for payment each month and must be accompanied by duplicates of State vouchers to show the expenditures made by the State to offset those of the Federal Government; and an individual pay check is sent directly to each Federal patrolman. The State officer is given as much authority and latitude as possible in the expenditure of Federal funds. He is placed in practically the same position as a National Forest supervisor, by being allowed a wide degree of discretion and by being held fully accountable for results. He selects the Federal patrolmen, instructs them in their duties, and supervises their work.

Federal patrolmen given police powers by the State.

The Federal patrolmen must be given such police powers for the prevention and control of forest fires as the laws of the State provide, they must be authorized to employ assistance in fighting fires, and they must be equipped with fire-fighting tools.

Federal inspection of work.

The Forest Service inspects the cooperative work on the protected areas. This is essential, since it serves to determine the efficiency of the plan of fire control and the effectiveness of the work done. Also it enables the Service both to give and to receive practical suggestions on the ground. The Service may, for cause, withdraw its approval of the expenditure of Federal funds on any area or terminate the Federal appointment of the State officer or of any Federal patrolman.

WORK DONE IN 1912.

The States which received Federal aid under the Weeks law in 1912 and the amounts expended by the Government are shown in the following summary:

State.[1]	Federal funds available for expenditure in States in 1912.			Expenditures in 1911 and 1912.	Unexpended balance of $200,000 fund, Jan. 1, 1913.
	Allotments.	Expenditures.[2]	Unexpended balances.		
Maine	$10,000	$6,514.50	$3,485.50	$16,506.30	.....
New Hampshire	8,000	7,720.90	279.10	13,940.40	.....
Vermont	2,000	1,997.15	2.85	3,215.15	.....
Massachusetts	2,500	2,489.00	11.00	2,854.00	.....
Connecticut	1,500	1,223.25	276.75	1,229.25	.....
New York	4,000	4,000.00	.....	6,000.00	.....
New Jersey	2,000	1,977.33	22.67	2,967.33	.....
Maryland	2,000	649.00	1,351.00	918.00	.....
Wisconsin	5,000	4,113.00	887.00	8,550.25	.....
Minnesota	10,000	10,000.00	.....	20,000.00	.....
Washington	10,000	2,818.75	7,181.25	2,818.75	.....
Oregon	10,000	7,103.05	2,896.95	10,408.05	.....
Total	67,000	50,605.93	16,394.07	89,407.48	$110,592.52

[1] Negotiations were started with Kentucky, Montana, and Idaho, but no agreements were executed.
[2] Federal expenditures in each State were at least equaled and in most cases considerably exceeded by State expenditures.

Federal funds are rarely expended over an entire watershed, but only on those portions which have most protective value, or which are most liable to fire damage. The watersheds which received cooperative protection were the following:

Watersheds protected.

Maine	St. Croix, Narraguagus, Union, Penobscot, Kennebec, and Androscoggin.
New Hampshire	Androscoggin, Saco, Connecticut, and Merrimac.
Vermont	Connecticut, Otter Creek, and Hudson.
Massachusetts	Nashua, Thames, Connecticut, Housatonic, and Hudson.
Connecticut	Thames, Connecticut, and Housatonic.
New York	Hudson and Delaware.
New Jersey	Hackensack, Passaic, Delaware, and Raritan.
Maryland	Potomac and Youghiogheny.
Wisconsin	Chippewa and Wisconsin (headwaters of the Mississippi).
Minnesota	St. Louis, Rainy, Mississippi, and Red River of the North.
Washington	Columbia, Chehalis, Cowlitz, Snohomish, Duwamish, Willapa, Puyallup, Skagit, Stillaguamish, Nooksak, Hoh, Soleduck, and Grays.
Oregon	Columbia, Willamette, Nehalem, Wilson, Siletz, Umpqua, Coos, Rogue, and Klamath.

Three hundred and eight Federal patrolmen were employed, of whom about 200 were on continuous pay from the date of appointment to the end of the season. They received from $1 to $3 a day. When not directly under the State forester, or warden, they were assigned to district wardens or rangers who supervised and inspected their work. The patrolmen are usually given specific written instructions as to routes of travel and other duties.

Number of Federal patrolmen.

Supervision of patrol.

Each had a district to guard varying in area from about 25,000 to 100,000 acres. Without necessarily attempting to cover the whole district he made his rounds of the dangerous places on the most valuable areas at the most advantageous times. These routes varied from 10 to 40 miles a day, depending on the most feasible method of travel, usually by foot, horseback, or bicycle. Along the railroad lines, except where oil-burning locomotives were used, there was a special and constant patrol, in some places on foot and in others on railroad velocipedes or speeders.

Area covered by patrol.

The patrolman carries a map of his district and adjoining districts showing the major topographic features and the approximate location of the Federal and State patrol routes, patrolman's and fire warden's headquarters, telephone lines, lookout stations, roads, trails, and tool-supply boxes, or any features which might aid him in an emergency. He also must carry some fire-fighting tool, such as a shovel or a collapsible canvas pail.

Equipment of patrolman.

The most important duties of the patrolman are putting out small fires, warning persons against setting or leaving fires, and recording their names when advisable. In the larger fires he has authority under the State law to call out help.

Duties of patrolman.

In addition to regular patrol duty and fire fighting, his work includes watching for fires from lookout stations, burning slash, and constructing protective improvements.

Lookout stations for primary control.

In most of the mountainous regions, especially in the Northeast, the lookout station is a highly developed feature of the State's fire protective system. It furnishes the primary control of the fire situation, while the patrol conducted in the valleys beneath forms the secondary control. The station is generally permanent, and consists of a lookout cabin or tower on top of a mountain, possibly with living quarters farther down where water can be had. The station is connected by telephone with the country below and with other lookouts, and equipped with field glasses, a map of practicable size, plane table, and alidade. Usually the watchman lives on the mountain, and during clear days is continuously on duty. In rainy or thick weather, when watching is not necessary or feasible, he is busy inspecting or repairing the telephone line or keeping clear the trail by which the line can be traveled quickly and damage to it located promptly. The watchman is supplied with a list of the names and telephone-call numbers of chief wardens, deputy wardens, patrolmen, watchmen, timberland owners, lumbermen, and all persons who may render help in the territory covered by the lookout; and he notifies the proper persons when he discovers a fire. From the mountain top he is generally able promptly to discover fires which might otherwise burn for hours and, perhaps, gather tremendous headway before they would have been detected from the lower valleys.

Telephone connections.

The practical value of the lookout station has been thoroughly tested; it is one of the best assets of a timbered country. Wherever possible the Federal Government prefers that its funds be expended for the salaries of lookout watchmen.

Protective improvements constructed.

When there was no need for patroling, the men were employed in the construction of protective improvements. In some States a great deal of work of this kind was accomplished in 1911 and 1912. An example of what may be done was furnished by Wisconsin.

There was practically no danger from forest fires on the cooperative area in Wisconsin after the middle of the usual dry season in either year. It would have been unwise to dismiss the patrolmen, since there was no telling when dry weather might come, and it would have been difficult to get hold of the same men again or others quite as competent. The improvement work, therefore, was pushed ahead rapidly to make the area more traversable and thus easier to protect. Nearly half of the area is State land included in the State forest reserve. The plan was to divide the more valuable portions, and those of greatest fire risk, into blocks of about 40 acres by constructing roads and fire lines so that the patrol force would have a reasonably good chance of holding a fire within the block in which it started. The roads are about 3 miles apart, and from them fire lines extend to such natural fire barriers as lakes, rivers, and wet swamps. For the most part, the roads were built by removing the ties from old logging railroad grades and then leveling the grades with plow and drag. This network of old grades throughout a large portion of the cooperative area made road construction comparatively inexpensive. Where the roads will become main thoroughfares care was taken to build them

Firebreaks constructed in Wisconsin.

for permanent use. Less expensive fire lines and trails seemed sufficient where fire protection was the only reason for their construction. There were constructed during 1911 and 1912 by the State and Federal patrolmen, with temporary help, over 159 miles of road and 118 miles of fire line.

A complete telephone system was planned and 56 miles of line were constructed, which connect a headquarters camp with distant and important lookout towers, ranger cabins, and summer resorts. This system will be still further extended during the summer of 1913.

Telephone lines built.

Other important protective measures were the "brushing out" of trails; the cutting of old stubs, chiefly birch, for a distance of 6 rods on each side of 69 miles of roads and fire lines; the burning of dangerous slashings on 1,800 acres; and the construction of 5 bridges, 4 ranger cabins, and 4 lookout towers.

The cost of this work in Wisconsin was a little over $26,000.

RESULTS ACCOMPLISHED.

There were many practical results of cooperation under the Weeks law. Hundreds of fires left by campers, fishermen, and hunters, or set by careless smokers and by locomotives, were discovered by the patrolmen and promptly extinguished. Great progress was made on permanent improvements that will simplify future fire control and prevention. But in addition to these tangible results, which have been apparent from the start, the educational value of the work although not measurable has been far reaching. Except in a few States, the last two years were the first when any systematic State patrol of the forests was conducted. It marked the general extension of the State organization cooperating with the Federal Government in getting out among the people; in educating them, through the actual work done, of the need and value of fire protection; and in encouraging their cooperation.

The public is educated.

The most effective work of the patrolmen was in warning persons met in the woods of the danger of setting fires, and informing them of the fire laws. The patrolmen were generally instructed to record the names and addresses of fishermen, hunters, and campers whenever possible and to send them to the district chief. In New Hampshire, in 1911, 4,200 warnings of this sort were given; more than half the names were recorded, and forwarded to the office of the State forestry commission. Before the fire season of 1912 a copy of the fire laws was sent to each of these persons.

Warnings given.

Sportsmen, loggers, and others who travel the woods are taking greater care in the use of fire; quicker notifications of fire are given to the proper State officer, while before they at best were desultory. Many private owners who were skeptical at the start later saw the practical value of the work and began cooperating in it and contributing toward it. The increased interest of the public was shown by the widespread demand for information on fire protection received by the various State foresters and by the Federal Forest Service.

Greater care by public.

State legislation encouraged.

The first direct result of the Weeks law in encouraging State legislation was the passage by the Connecticut Assembly of the following act:

CHAPTER 292.

AN ACT CONCERNING PREVENTION OF FOREST FIRES.

Be it enacted by the Senate and House of Representatives in General Assembly convened:

SECTION 1. The State forest fire warden may take such action as he may deem necessary to provide for the prevention and control of forest fires in groups of towns, and is hereby authorized to enter into an agreement with the Secretary of Agriculture of the United States, under authority of the act of Congress of March 1, 1911, for the protection of the forested watersheds of navigable streams in this State. Said State forest fire warden may appoint patrolmen, who shall receive not more than twenty-five cents per hour for time actually employed, and may establish and equip fire lookout stations and furnish necessary equipment for such patrolmen.

SEC. 2. Any patrolman appointed for such purpose by said State forest fire warden may arrest, without warrant, any person taken by him in the act of violating any of the laws of this State for the protection of forest and timber lands.

SEC. 3. The disbursements of the State forest fire warden in carrying out the purposes of this act shall be paid by the State from the appropriation for fire wardens.

SEC. 4. This act shall take effect from its passage.

Approved, September 26, 1911.

Practical results in saving property.

The first question that naturally occurs to one looking for measurable results is how far the expenditures succeeded in preventing fire losses. Maine and New Hampshire furnish striking examples of comparative losses in 1903 and 1911, two of the most dangerous fire years on record in these States. The comparison is based only on the watersheds where cooperative fire protection between the Federal Government and the State and timberland owners was established last year.

Year.	Season of drought.	Maine.		New Hampshire.	
		Acres burned.	Damage.	Acres burned.	Damage.
1903	Apr. 17 to June 6	172,040	$679,423	84,255	$200,000
1911	Apr. 16 to June 1, June 20 to July 17	91,471	154,284	10,925	34,036

While the danger season of 1911 was longer and generally considered to be the more severe, the area burned over and the amount of damage were considerably less than in 1903, and the decrease without doubt can be attributed in great measure to the protection afforded in 1911, as compared with the almost utter lack of it, except by a few private owners, in 1903.

EXTENDING COOPERATIVE PROTECTION.

The Federal Government desires to extend this cooperative protection to other States. To secure its benefits they must enact a forest-fire law and must appropriate funds for administering it.

Few more effective steps could be taken by many States toward the conservation of resources which support important industries than to inaugurate systematic fire protection. The fact that the immediate financial interests of timber owners make them backward in undertaking this insurance of their industry is an additional reason for the States to take the lead. The readiness of the Federal Government to cooperate with the States, under the terms of the Weeks law, as soon as the State makes a start, is an incentive to immediate action.

The States should take the lead.

A State forest-fire law should provide, in addition to an organization to fight fires, a patrol force for fire prevention. A general defect in fire laws is that they provide only for fighting fires and not for patrol. The law should, of course, carry an adequate appropriation; the most serious defect has been the inadequacy of appropriation. To protect the National Forests costs about 2 cents an acre annually; the Biltmore tract in North Carolina, about 5 cents an acre; and the lands of the various timberland protective associations in the Northeastern and Northwestern States, from 2 to 4 cents an acre. It is probable that the State can secure efficient protection for 1 cent an acre, if the larger private owners will assist by contributing toward the protection of their own lands. If, for example, a State contains 5,000,000 acres of forest land which needs protection, an annual expenditure of $50,000 should be sufficient to handle the work effectively. It is improbable that a State would appropriate this amount at the beginning; an appropriation of $10,000 or even less would be sufficient to start the work and demonstrate its value.

What a fire law should provide.

Cost of protection.

APPENDIX.

FORM OF AGREEMENT.

The form of agreement between the Secretary of Agriculture and the State for the protection from fire of the forested watersheds of navigable streams is as follows:

UNITED STATES DEPARTMENT OF AGRICULTURE.

Agreement for the protection from fire of the forested watersheds of navigable streams under section 2, act of March 1, 1911 (36 Stat., 691).

This agreement, made by and between the Secretary of Agriculture of the United States, under authority of section 2 of the act of Congress approved March 1, 1911 (36 Stat., 691), and the State of _____ by and through its State Forestry Commission, witnesseth:

That whereas the said State has requested the cooperation of the said Secretary in the protection from fire of the forested watersheds of navigable streams; and

Whereas the said State has provided by law for a system of forest-fire protection;

Now, therefore, the said parties do mutually promise and agree with each other as follows:

1. To establish and maintain a cooperative fire-protective system covering any or all private or State forest lands within the State of _____ and situated upon the watersheds of navigable rivers; and to furnish for this purpose Federal and State patrolmen or to take such other protective measures as may be deemed advisable, under the conditions hereinafter provided.

2. The State commission shall furnish maps showing the watersheds and areas which are proposed to be protected under this agreement. The cooperation shall be limited to such watersheds and areas in so far as they shall be approved by the Secretary. The said commission shall indicate the periods during which protection from forest fires is proposed under this agreement; the number of patrolmen, with their stations, which will be employed by the State; the character and extent of other protective measures which it is proposed to put into effect at the expense of the State; and the localities in which it is desired to place Federal patrolmen furnished by the Forest Service.

3. The State forester of _____, acting as an employee of the State commission, shall be appointed collaborator in the Forest Service of the United States Department of Agriculture at a salary of one dollar ($1) a month, and acting in such capacity shall have direct charge of the force of Federal patrolmen employed under this agreement. The State forester shall select the Federal patrolmen, subject to approval by the Secretary, instruct them *in writing* as to their duties, supervise their work, and certify to their services on pay rolls of the Forest Service.

4. The Federal patrolmen so selected shall be appointed as temporary laborers in the Forest Service at a per diem rate not exceeding _____ dollars ($____); provided that they shall be employed exclusively in the protection of areas on the watersheds of navigable rivers which shall have been approved by the said Secretary.

5. This agreement contemplates the employment under ordinary conditions of fire hazard of not to exceed _____ Federal patrolmen, or in case of emergency of not to exceed _____ Federal patrolmen in the discretion of the collaborator, provided that in case of serious emergency the latter number may be increased with the approval of the Forester.

6. The State commission shall secure for the Federal patrolmen furnished under this agreement, by appointment as deputy State fire wardens or otherwise, without additional compensation, such police powers for the prevention and control of forest fires as may be granted under the laws of the State of _____, and shall equip such Federal patrolmen with such fire-fighting tools or devices and shall authorize them to employ such assistance in fighting fires as its funds and the State fire laws and regulations will permit.

7. The total sum to be expended by the Federal Government during any Federal fiscal year for the purposes of this agreement may equal but shall not exceed _____ dollars ($____); but in no case shall the amount expended by the Federal Government in any Federal fiscal year exceed the amount appropriated by the said State for and expended by it during the same period for the purpose of protecting from fire forested watersheds of navigable streams in said State. This agreement contemplates an expenditure of State funds of at least _____ dollars ($____); and in the event of such expenditure falling below said amount the Federal expenditure will be decreased proportionately.

8. Payment for the services of Federal patrolmen employed under this agreement shall be made at the end of each calendar or fractional month on vouchers certified by the State forester as collaborator, and forwarded to the Forester, Forest Service, Washington, D. C., provided that no patrolman will be employed except during the real danger season from forest fires on the watersheds and areas approved by the Secretary under this agreement.

9. The said Secretary and his authorized representative shall have full authority to inspect the protective areas and the force herein authorized, and at his option, by giving the State commission written notice, may withdraw his approval of any such area or portion thereof, or terminate the employment of any Federal patrolman or patrolmen or of the State forester as collaborator in the Forest Service.

10. The State forester shall be responsible for seeing that each patrolman keeps a vigilant lookout for forest fires in or threatening his district, and that he makes every possible effort to extinguish such fires as occur whether they are on lands belonging to the State, the Federal Government, or a private owner, provided that during the patrol period when in the judgment of the State forester patrol is unnecessary the patrolmen may be used on other fire-protection work. The State forester or his representative shall from time to time make such personal inspection of the cooperative fire-protection work done under this agreement as may be necessary to promote the effectiveness of said work.

11. The said State forester shall, with respect to all private forest land afforded protection against fire under this agreement, use every proper means to bring about the active cooperation of the owner in such protection, including aid from him in the form of hire of one or more patrolmen, construction of permanent improvements, and the like.

12. Both the State commission and the Forest Service of the United States Department of Agriculture shall have equal right to publish the results of the cooperation under this agreement: *Provided*, That any results intended for publication, except press notices of momentary or local interest, be approved by the commission and by the Secretary. In all such publications it shall be plainly stated that the results were secured through cooperation between the commission and the Secretary.

13. This agreement shall become effective on the _____ day of _____, 191—, and shall continue in force thereafter, subject, nevertheless, to the availability of funds appropriated by Congress by the act of March 1, 1911, for the purposes herein mentioned, and to any amendments which may be made hereof by mutual agreement of the parties; and it is expressly understood that this agreement or any modifications hereof may be terminated by either party upon thirty (30) days' written notice to the other.

In witness whereof the said commission has hereunto caused its name and seal to be affixed by its proper officers, on the _____ day of _____, 191—, and the said Secretary has hereunto set his hand and affixed his official seal on the date below written.

_____ _____,
President, State Forestry Commission.

_____ _____,
Secretary of Agriculture.

Signed and sealed by the Secretary of Agriculture this ____ day of _____, 191—.

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6. The State commission shall secure for the Federal patrolmen furnished under this agreement, by appointment as deputy State fire wardens or otherwise, without additional compensation, such police powers for the prevention and control of forest fires as may be granted under the laws of the State of _____, and shall equip such Federal patrolmen with such fire-fighting tools or devices and shall authorize them to employ such assistance in fighting fires as its funds and the State fire laws and regulations will permit.

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8. Payment for the services of Federal patrolmen employed under this agreement shall be made at the end of each calendar or fractional month on vouchers certified by the State forester as collaborator, and forwarded to the Forester, Forest Service, Washington, D. C., provided that no patrolman will be employed except during the real danger season from forest fires on the watersheds and areas approved by the Secretary under this agreement.

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_____ _____,
President, State Forestry Commission.

_____ _____,
Secretary of Agriculture.

Signed and sealed by the Secretary of Agriculture this ____ day of _____, 191—.

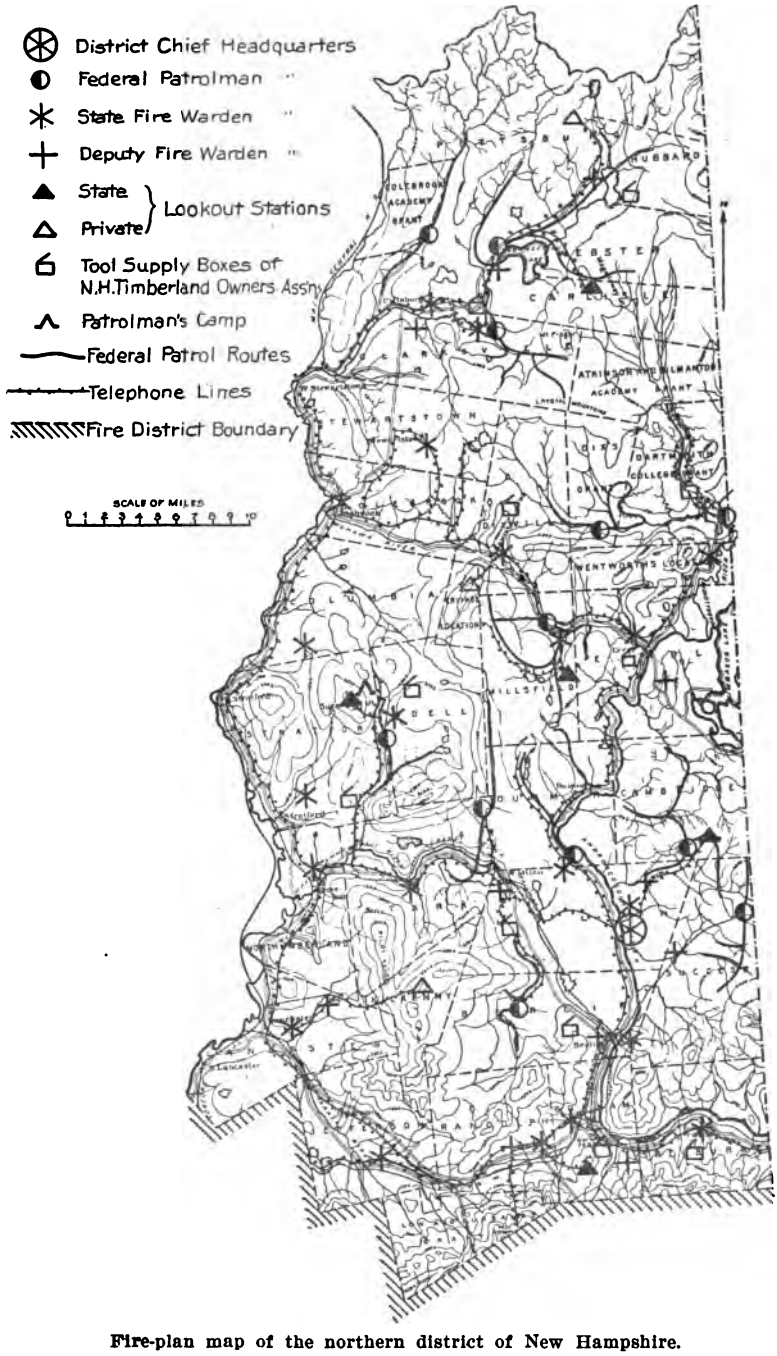
FIRE-PLAN MAP.

The accompanying map of the northern district of New Hampshire, including a portion of the cooperative watersheds, is an example of the kind which should accompany a fire-protection plan. The map shows, in addition to the headquarters of members of the fire force, the routes of patrolmen and the location of lookout stations, telephone lines, and tool-supply boxes.

This district has an area of approximately 1,000,000 acres. It is supervised by a district chief, under whom are patrolmen, lookout watchmen, and fire wardens. In this district in 1912 the expenditures for fire protection were as follows:

State	$4,850
New Hampshire Timberland Owners Association	5,270
Federal Government	2,580
Total	12,700

At $12,700 for the protection of 1,000,000 acres, the rate is about 1¼ cents per acre.



Fire-plan map of the northern district of New Hampshire.

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Issued July 18, 1912.

U. S. DEPARTMENT OF AGRICULTURE,

FOREST SERVICE—Circular 206.

HENRY S. GRAVES, Forester.

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FOREST PRODUCTS LABORATORY SERIES.

COMMERCIAL CREOSOTES

WITH SPECIAL REFERENCE TO PROTECTION OF WOOD FROM DECAY.

BY

CARLILE P. WINSLOW,

In Charge, Cooperative Projects, Forest Products Laboratory.

WASHINGTON:
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COMMERCIAL CREOSOTES WITH SPECIAL REFERENCE TO PROTECTION OF WOOD FROM DECAY

PURPOSE OF THE STUDY.

The aim of this circular is to tell the more important sources of wood-preserving creosotes, the methods used in their production, their general properties, and the quality, price, and quantity of the creosotes annually consumed in this country. As a whole, it is intended more for the consumer who is unfamiliar with the various products sold as creosote than for the chemist or manufacturer, who is well informed on their technical qualities.

For some years the Forest Service has conducted investigations regarding the properties and methods of analysis of various creosotes and the more important of the results secured have been published.[1] This work has been, and will be, continued. The major part completed at the present time, which is embodied in this report, is an investigation of the quality and prices of the creosotes available commercially. For this study, samples of creosote were collected from manufacturers and dealers throughout the country and were critically analyzed. At the same time, information was secured from the dealers as to prices, and statistics were collected on the annual consumption.[2]

Further and more extensive investigations are now under way at the Forest Products Laboratory maintained in cooperation with the University of Wisconsin, at Madison. Samples of a large number of authentic coal tars, oil tars, and wood tars have been collected, from which creosotes are being distilled and critically analyzed and examined. At the same time experiments are being conducted to determine the comparative efficiency of various creosotes as wood pre-

[1] Forest Service Circular 80, Fractional Distillation of Coal-Tar Creosote, by Arthur L. Dean and Ernest Bateman; Circular 98, Quantity and Character of Creosote in Well-Preserved Timbers, by Gellert Alleman; Circular 112, Analysis and Grading of Creosotes, by Arthur L. Dean and Ernest Bateman.

[2] Mr. H. F. Weiss, assistant director, forest products laboratory, planned the work and collected the samples of creosote. Mr. Ernest Bateman, chemist in forest products, furnished much of the information and directed the analysis of the samples. Mr. C. H. Teesdale, assistant engineer in forest products, actually conducted the analyses.

servatives. It is hoped that through this work the wood-preserving value of any creosote can be foretold with a fair degree of certainty for any specific condition of service, simply by a knowledge of its physical and chemical characteristics without regard to its source or method of production.

Because of the present lack of knowledge of the properties of all of the various creosotes which may be produced, the terms, definitions, and classifications proposed and used in this publication are subject to criticism and possible future modification. The limits described for the several classes are based on physical and chemical properties possessed by creosotes produced from the sources, or by the methods specified. It is possible that creosotes from other sources may be found to possess similar properties, yet no other method which will indicate the source more satisfactorily than that discussed in this publication is now known to the Forest Service.

DEFINITIONS.

Much misunderstanding exists as to the meaning of the term "creosote." It is defined by the Standard Dictionary as "a colorless to yellowish oily liquid compound consisting of a mixture of phenols distilled from wood, and having a smoky odor and burning taste. It is a powerful antiseptic and is used for the preservation of timber, meat, etc.; called also oil of wood tar and oil of smoke." Allen, in his Commercial Organic Analysis, says: "The name 'kreosot' was first applied by Reichenbach, in 1832, to the characteristic antiseptic principle contained in wood tar. Carbolic acid was discovered soon after by Runge in coal tar, and was long confused with the wood-tar principle; and the crude carbolic acid from coal tar is still known as 'coal-tar creosote.' Somewhat similar products are now obtained from other sources, so that much confusion has arisen. The term 'creosote,' when used without qualification, ought to be understood as signifying the product from wood tar, but it is better to describe Reichenbach's body as 'wood-tar creosote,' and employ the unqualified word 'creosote' in a generic sense as meaning the mixed phenols and phenoloid bodies obtained from wood tar, coal tar, blast-furnace tar, shale oil, bone oil, or other sources."

In its original meaning, therefore, the term "creosote" was applied to a product obtained from wood, and the term is still used thus in pharmacy, and refers to a refined product derived from the destructive distillation of beech or other hardwood. However, with the development of both the wood-preserving and the coal-tar industries, the term "creosote oil," frequently abbreviated to "creosote," gradually came to be applied to the heavy distillates from coal tar, and the use

of the term has become more and more extended until, at the present time, it is commonly used in referring to the distillates heavier than water from any tars or tarlike substances, and is even erroneously used to cover products containing admixtures of undistilled tar or pitch. As a result of this lax use of the word it conveys but little to those conversant with the subject and is confusing to those unfamiliar with commercial practice. More specific terms are evidently needed to properly differentiate between the various creosotes. The most useful classification from the wood preserver's point of view would be one based upon the merits of the various products, but lack of sufficient data renders this impossible. The only practical classification at present must be based upon the source and method of production. The following terms and definitions are suggested, and will be used in this publication:

1. *Creosote* is a distillate heavier than water obtained by the distillation of a tar or a tarlike substance.

2. *Coal-tar creosote* is a creosote derived from coal tar produced by the destructive distillation of coal at a temperature high enough to produce a tar consisting, for the most part, of hydrocarbons of the aromatic series.[1]

3. *Oil-tar creosote*[2] is a creosote derived from oil tar. This tar may be obtained from the destructive distillation of petroleum in a gas retort, producing oil gas as a main product and oil-gas tar as a by-product, or by the cracking of gas oil in the carburetor of a water-gas plant producing carbureted water gas as a main product and carbureted water-gas tar as a by-product.

4. *Wood-tar creosote* is a creosote derived from a tar produced by the destructive distillation of wood.

5. *Mixed creosote* is a creosote produced by mixing other material with a given creosote, such as another creosote, pitch, undistilled tar, or petroleum, or it may be secured by the distillation of a mixture of two or more tars or tarlike substances. In view of the similarity between certain mixed creosotes and creosotes obtained by the distillation of coal tar, produced at temperatures sufficiently low to permit the production of hydrocarbons of the paraffin series, these latter distillates are also classed under this heading. The terms "mixed coal-tar creosote," "mixed oil-tar creosote," and "mixed wood-tar creosote" may be used according to the character of the material which predominates in the mixture.

---

[1] Creosote secured from coal tar produced at sufficiently low temperature to permit the production of hydrocarbons of the paraffin series might also be included under the name of coal-tar creosote, but in view of the paraffin hydrocarbons it is classed in this publication as mixed coal-tar creosote.

[2] Inasmuch as the derivatives of oil-gas tars and water-gas tars contain no phenoloid bodies, the use of the term "creosote" in this connection might, from a purely technical standpoint, be considered erroneous. However, the term is used commercially at the present time in this connection, and a careful consideration of the various definitions used in this publication should prevent any misunderstanding.

PRODUCTION OF CREOSOTES.[1]

SOURCE OF TARS.

Although there are a variety of tars from which creosotes may be produced, the most important commercial ones may be classified as coal tars, oil tars, and wood tars. The sources and general methods of production of these tars are as follows:

Coal tars.

The important coal tars are derived chiefly from two sources: The destructive distillation of bituminous coal at high temperatures and the combined distillation and combustion of bituminous coal at comparatively low temperatures. The first, which furnishes by far the greater proportion of the total supply, is produced in the manufacture of coke and gas in by-product retorts and gas-house plants. Bituminous coal is destructively distilled at temperatures varying from 1,500° F. to 3,000° F., until the charge has been reduced to coke. During the process the ammoniacal liquor and tar are separated from the generated gases by condensation and washing. The tars naturally vary in their properties according to the character of the coal, and of the retorts, and according to the temperatures used. These factors in turn are largely dependent upon which of the two main products, gas or coke, is primarily desired; tar acids, however, are always present in the tars and usually the temperatures are sufficiently high in both cases to produce tars consisting largely of hydrocarbons of the aromatic series.

Coal tars produced at relatively low temperatures differ from those produced at higher temperatures in the character of their hydrocarbons. Since the temperatures are not high enough to transform all of the hydrocarbons to the aromatic series, the tars contain, to a greater or less extent, hydrocarbons of the paraffin group. Tars secured from blast furnaces using bituminous coal as fuel and from the Mond producer plants, where bituminous coal is used in the manufacture of gas for power purposes, are representative of this group. The production of such tars, however, is not extensive in this country.

Oil tars.

Of the oil tars, that produced in the manufacture of water gas is by far the most important in its relation to the manufacture of creosote. The method of production is, in general, as follows: The "generator" is charged with coke or anthracite coal, which is burned by the aid of an air blast to a cherry red. The hot gases so formed are passed

[1] Creosotes consist of complex mixtures of organic compounds, which may, however, be grouped into a comparatively few classes distinguished by their characteristic physical and chemical properties. For a more complete discussion the reader is referred to any standard textbook on organic chemistry.

through the "carbureter" and "superheater," which consist of vertical cylindrical chambers filled with a checker work of fire brick. After these bricks are heated to the proper temperature the air blast is discontinued and steam is blown into the generator. The gases formed by the contact of the steam with the hot coke or coal pass into the carbureter, into which petroleum "gas oil" is sprayed at the same time. This oil is partially cracked by the high temperature of the fire brick and combines with the gases from the generator to increase their illuminating power; the process of cracking continues through the superheaters. The gas is then passed to the condensers and washers, where tar is condensed and collected. This tar differs in its constituents from coal tar produced in the by-product coke ovens and gas retorts both in the absence of tar acids and in the presence of hydrocarbons of the paraffin series; usually, however, the quantity of paraffin hydrocarbons present is comparatively small.

Some oil tar also is produced by the destructive distillation of crude petroleum in the manufacture of oil gas. In tars from this source the quantity of paraffin hydrocarbons present is generally much greater than in that produced in the manufacture of carbureted water gas.

Wood tars.

Wood tar is produced in a manner somewhat similar to that in which by-product coal tar is formed. Wood is destructively distilled in retorts, and charcoal is produced, together with gas and a liquid distillate which consists largely of pyroligneous acid and a product called crude tar. The tar and acid are separated by settling and by distillation. Wood tars are quite different from coal tars and contain, in particular, less of the aromatic hydrocarbons.

DISTILLATION OF CREOSOTE FROM TARS.

From any or all of the foregoing tars, either alone or in mixture, creosote may be produced. The general process of manufacture is similar in all cases. The tar is distilled in a metal retort or still and the vapors are condensed and collected. Those distillates which are heavier than water form the true creosotes used in wood preservation. The temperatures at which the creosotes are obtained vary greatly, but generally lie between about 200° and 360° C. The actual temperatures in each case depend largely upon the character of the residue desired. In the United States the manufacture of creosote from coal tar is generally secondary to the manufacture of soft pitch; and in such cases the maximum temperature during the distillation is comparatively low. In Europe, on the other hand, coal tar is distilled largely for the production of the coal-tar dyes, and the distillation

is carried to higher temperatures. The creosote, therefore, contains a relatively greater amount of the higher boiling constituents than the American product.

As already stated, pitch, undistilled tar, or other similar materials are frequently mixed with a creosote, and while such mixtures are sometimes sold as creosotes, the term is improperly applied except as it relates to the distilled product.

GENERAL REQUIREMENTS OF WOOD-PRESERVING OILS.

The value of any creosote as a preservative against decay is fundamentally dependent upon its ability to prevent the development of wood-destroying fungi. This prevention may be accomplished in either of the following ways:

1. By introducing a material sufficiently poisonous to wood-destroying fungi to prevent their development.

2. By introducing a material which will sufficiently exclude moisture or air to reduce the amount of either below that required by the fungi for their development.

In the past the creosotes which have been successful have generally possessed, at least to some extent, both of these properties; but the first is generally considered the more essential. In recent years, however, there has been some tendency to use materials not markedly antiseptic, but primarily intended to exclude moisture. As yet, however, it has not been completely demonstrated, nor generally accepted, that a product can be obtained to fullfil entirely the second requirement.

Aside from these considerations, it is of course essential that the creosote be of such a nature as to remain in the wood for the desired period of protection. In this connection its relative solubility in water and its volatility are important. However efficient it may be in poisoning the food supply or preventing the absorption of moisture, if it will not remain in the wood with a considerable degree of permanence, its ultimate value will be small. Where the treated wood is to be placed in wet situations or under water, as in the case of piling, a soluble preservative is inefficient; and a volatile preservative is especially unsuited for timbers exposed to the air in warm climates.

The relative ease with which a preservative can be injected is of much importance in wood-preserving operations; for this reason a product which is not sufficiently fluid at temperatures which can be conveniently used at commercial treating plants is undesirable. The presence of free carbon is known to decrease the penetrance of creosote and for this reason is objectionable.

COMPOSITION AND PROPERTIES OF CREOSOTES.

The complexity of the many hydrocarbons and their derivatives which may be produced in the destructive distillation of coal, oil, and wood, makes it impossible to state precisely the nature of the various constituents of all creosotes. However, they may be broadly divided into two classes, compounds of the aromatic series and compounds of the paraffin series. The characteristic difference between the two lies in the greater chemical activity of the former. Coal-tar creosote consists almost wholly of aromatic compounds, and the long period of successful use of such creosote has led to the general feeling that these constituents are the more desirable.

The compounds of the aromatic series may be divided into three groups, as follows: (1) "Light oils," which distill below 205° C. and consist largely of phenols and cresols, or tar acids; (2) naphthalenes, which distill between approximately 205° and 255° C.; and (3) constituents of an anthracene nature distilling above 255° C, which will be referred to collectively as "anthracenes." Some or all of these are found in most creosotes.

Of these constituents the tar acids possess the highest antiseptic properties; they are, however, soluble in water and are more volatile than the other constituents. The naphthalenes and anthracenes are neither so antiseptic nor so volatile as the tar acids and are practically insoluble in water. There is much discussion as to the relative value of these different constituents, but, largely as a result of experience, the presence of tar acids is believed by many to be essential. While a large proportion of naphthalene is sometimes advocated, particularly for the preservation of piling, a reduction in the quantity of this constituent, with a corresponding increase in the amount of anthracenes, is believed to increase the value of a creosote for general purposes.

COAL-TAR CREOSOTES.

Figure 1[1] shows graphically the derivation and general composition of coal-tar creosote. The relative quantity of tar acids, naphthalenes, and anthracenes will of course vary according to the character of the tar and the temperatures used during its distillation, but generally the tar acids present will not exceed 5 per cent, the naphthalenes will comprise from 15 to 50 per cent, and the anthracenes will comprise the remainder. As previously defined it contains practically no paraffin hydrocarbons. The creosote as a whole is antiseptic, insoluble in water, and somewhat volatile; it is sufficiently

[1] In figs. 1 and 2, and Table 1, the term "solid at room temperature" (20° C.) is used in describing the condition of certain of the fractions distilled from creosote, when, at the ordinary temperature of a room, they retained their position in the receiving flask when vigorously shaken.

free from "free carbon," and fluid enough at temperatures used in commercial treating plants, to offer no great resistance to entrance into the wood.

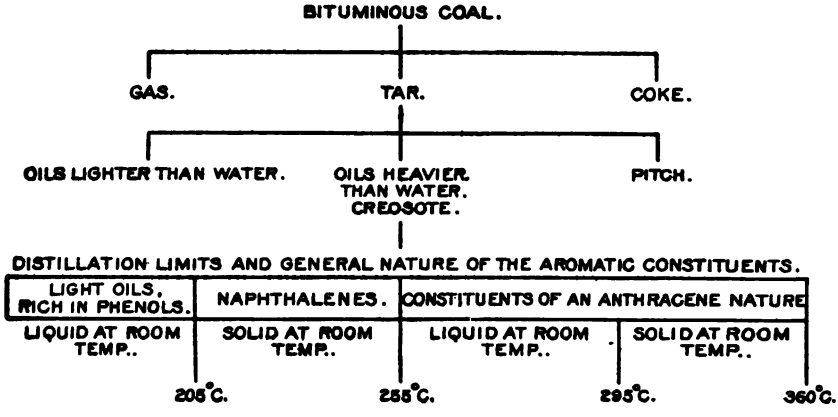

FIG. 1.—Derivation and general composition of coal-tar creosote.

WATER-GAS-TAR CREOSOTES.

Of the oil-tar creosotes, that from water-gas tar is practically the only one used for wood preservation. Figure 2 illustrates its derivation and general composition. This creosote is no more volatile

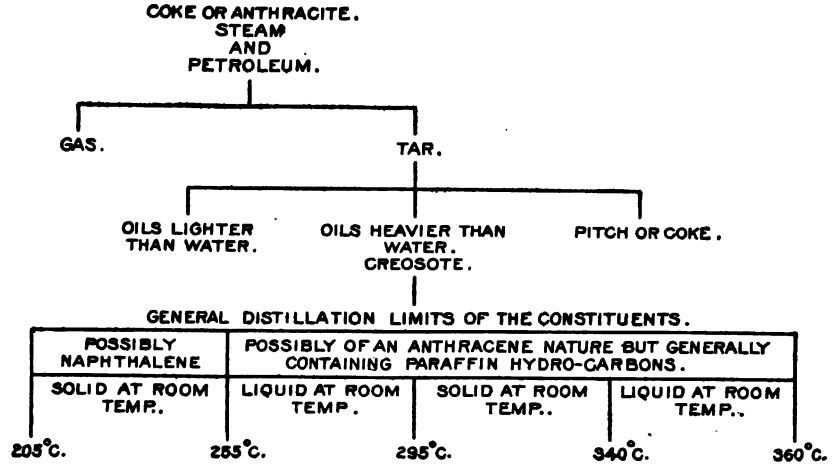

FIG. 2.—Derivation and general composition of water-gas-tar creosote.

nor soluble in water than coal-tar creosote, contains no "free carbon," and offers no marked resistance to entrance into the wood. In fact, water-gas-tar creosote may be produced which on fractional distilla-

tion will display a great similarity to coal-tar creosote. There is a difference, however, in the constituents of the two creosotes, as shown by the difference in certain physical properties of fractions distilled from them at equal temperatures. Furthermore, water-gas-tar creosote is distinctive in the absence of phenols and cresols, and usually in the presence of hydrocarbons of the paraffin group; it is not so antiseptic as coal-tar creosote.

WOOD-TAR CREOSOTES.

Of the wood-tar creosotes, that most used in the past has been secured from resinous woods. The derivation of such creosotes is illustrated in figure 3. Lack of authentic data prevents even a general statement as to its constituents, but the proportion of tar acids

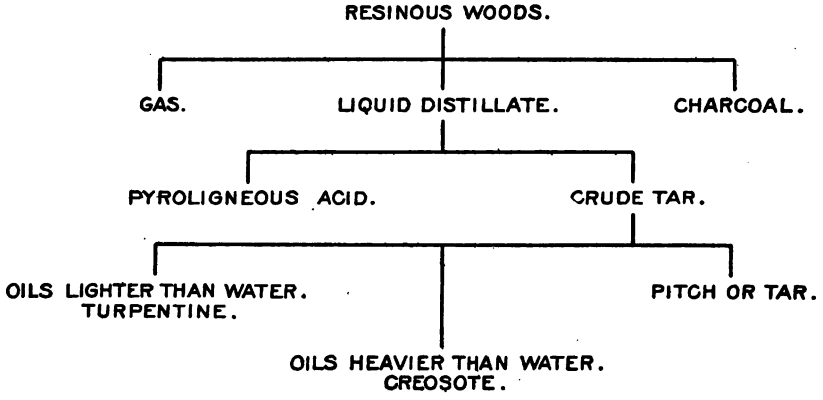

FIG. 3.—Derivation of wood-tar creosote from resinous woods.

and volatile constituents is generally greater, and of naphthalene and anthracene much less, than in the coal-tar creosotes. Wood-tar creosotes have been used to some extent as wood preservatives for many years, but partly as a result of their comparatively high cost and limited production and partly through lack of authentic data regarding their efficiency, they do not rank in importance with the other creosotes.

MIXED COAL-TAR CREOSOTES.

A large part of the creosote produced in this country falls into the class of mixed coal-tar creosote. Some is made by the mixture of undistilled coal tar, or oil tar, or pitch, with coal-tar creosote; some is produced by the partial distillation and combustion of bituminous coal at comparatively low temperatures; and some is secured through the manufacture of soft pitch when coal tar and water-gas tar are

distilled in admixture. The nature of all mixed coal-tar creosotes can not be described, because their constituents and relative merits as wood preservatives vary in each case according to the materials used in their production and preparation. Admixtures of undistilled tar or pitch containing free carbon will, however, tend to decrease the penetrance of the creosote, while the admixture of products which contain appreciable amounts of constituents of the paraffin series will doubtless affect in some measure the antiseptic properties of the creosote.

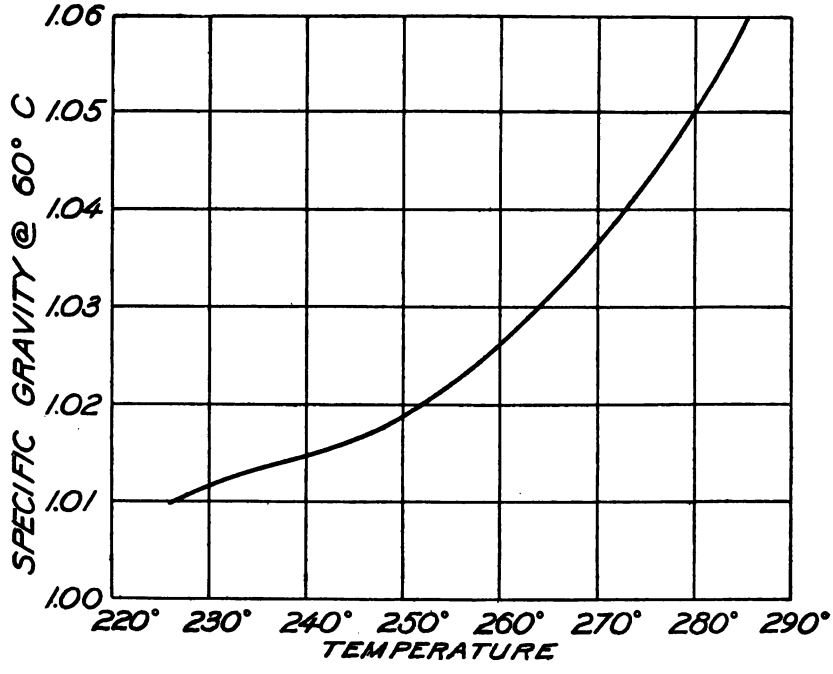

FIG. 4.—Lower limits for specific gravities of fractions from coal-tar creosote.

DISTINCTIVE PROPERTIES OF COAL-TAR CREOSOTES AND MIXED COAL-TAR CREOSOTES.

Whatever may be the individual opinion as to the merits of the various creosotes as wood preservatives, and no matter what creosote may be selected for use, it is obvious that the consumer ought to have some means of determining the source and nature of the material which he purchases. The Forest Service has not as yet sufficiently investigated all creosotes to permit a definite correlation of their physical and chemical properties with sources and methods of production; but certain characteristic properties of authentic coal-tar creosotes and mixed coal-tar creosotes, from several sources, have been determined with a considerable degree of certainty.

The more important points to be noted are:[1]

1. In the fractional distillation of the coal-tar creosotes the percentages of distillate coming over between the same temperatures, although varying widely for different creosotes, fell within fairly definite limits.

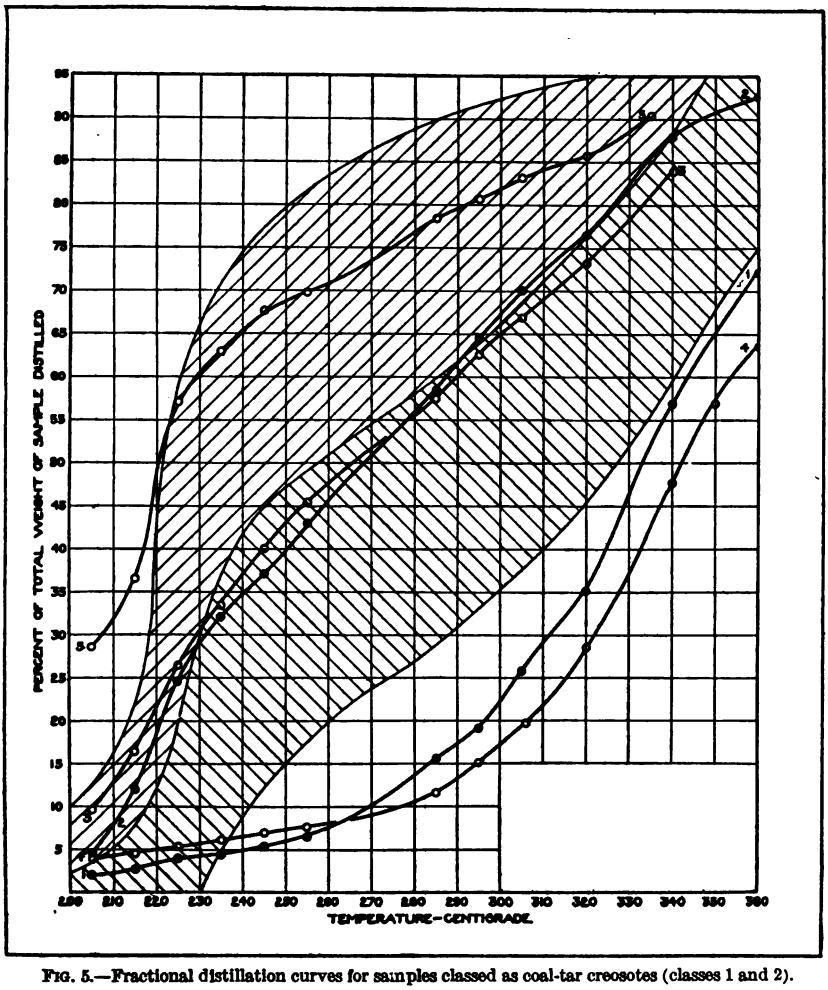

FIG. 5.—Fractional distillation curves for samples classed as coal-tar creosotes (classes 1 and 2).

2. With the coal-tar creosotes the fractions distilling above 320° C. did not melt at a temperature as low as 60° C., while similar fractions from creosotes with which petroleum products, such as water-gas-tar

[1] These are discussed in Forest Service Circular 112, Analysis and Grading of Creosotes, by A. L. Dean and E. Bateman. The method of analysis used in these investigations, and described in Circular 112, is reprinted in the appendix to this publication.

creosote or the undistilled tar had been mixed, generally melted at that temperature.

3. With certain of the mixed coal-tar creosotes secured from coal tar produced by the combined distillation and combustion of bituminous coal at comparatively low temperatures the proportion of tar acids was high as compared to that from the coal-tar creosotes.

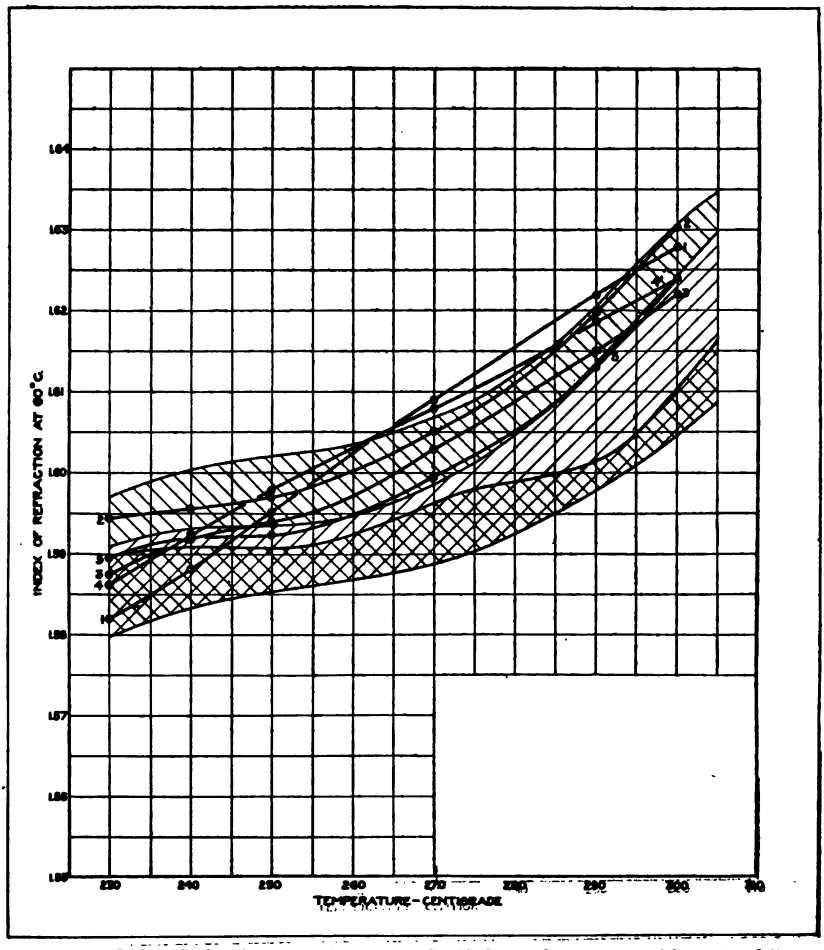

FIG. 6.—Index of refraction curves for samples classified as coal-tar creosotes (classes 1 and 2).

4. The most constant and serviceable physical properties were the index of refraction and specific gravity of certain of the fractions. These properties of fractions distilling between the same temperature limits were uniformly higher for the coal-tar creosotes, or those rich in aromatic hydrocarbons, than for those containing paraffin constituents. As a rule, the greater the quantity of paraffin hydrocar-

bons present in the fraction the lower the index of refraction and the specific gravity.

5. The most satisfactory chemical test was the "sulphonation test." The residues from the sulphonation test were larger as the quantity of paraffin hydrocarbons in the creosote increased. This is to

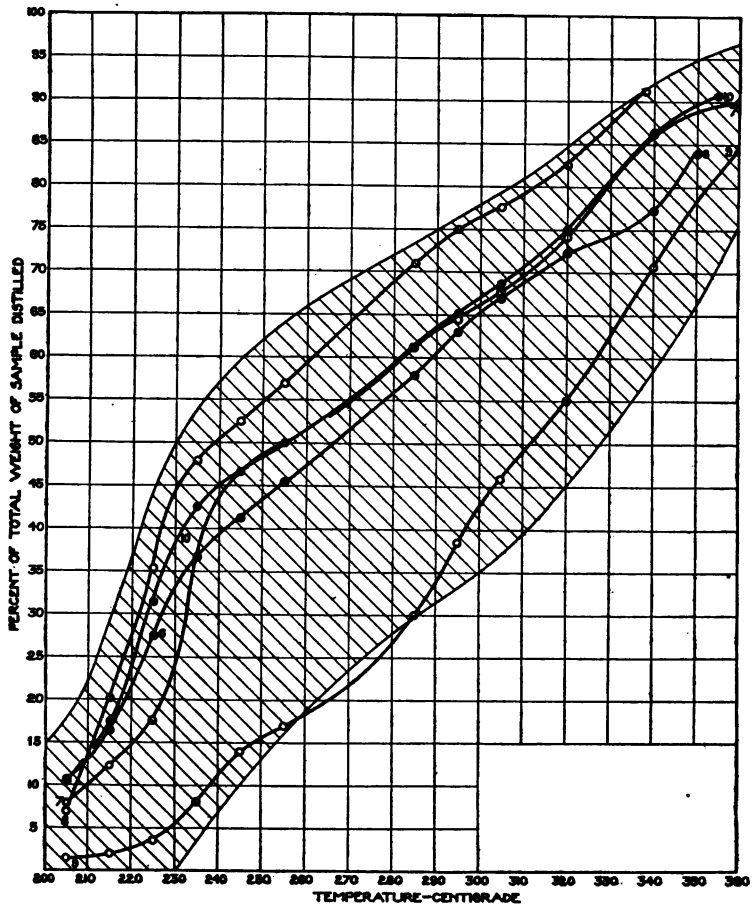

FIG. 7.—Fractional distillation curves for samples classified as mixed coal-tar creosotes (class 1).

be expected, because, with the exception of a possible oily residue, which is readily soluble in caustic alkalies, there is no residue from aromatic hydrocarbons alone.

From these results it was possible to divide the creosotes which were examined into several classes according to their properties. A

classification adapted from that given in Circular 112 is here tentatively proposed.[1]

Coal-tar creosotes.

Coal-tar creosotes consist almost entirely of aromatic compounds, but are divided into two classes, according to the relative proportion

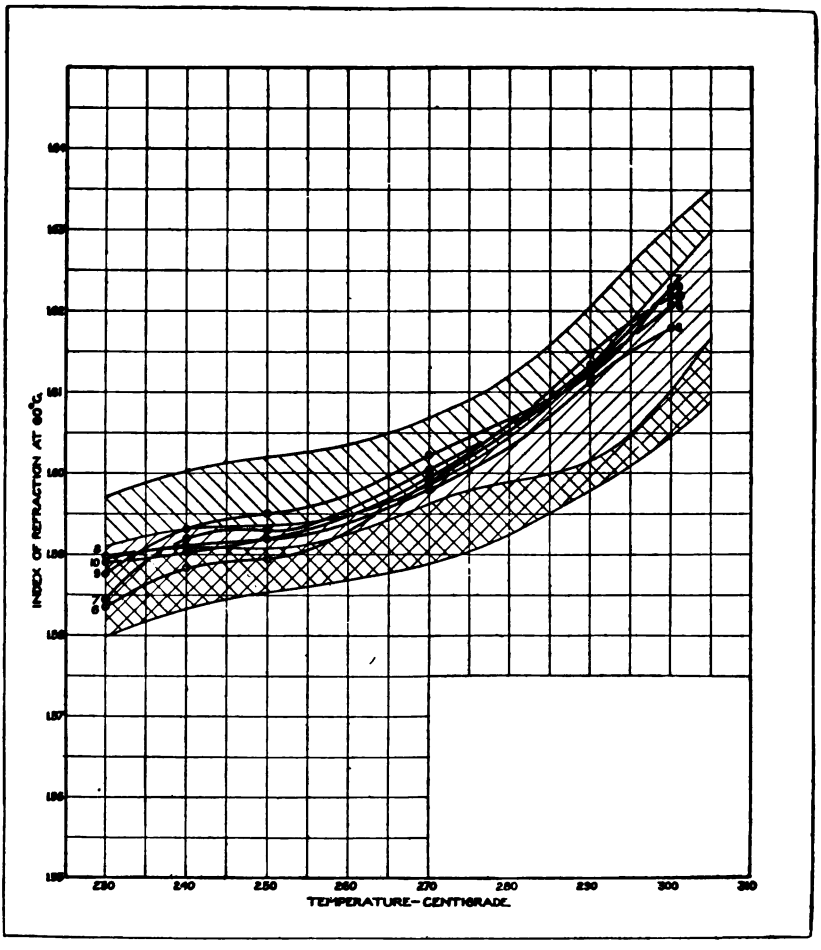

FIG. 8.—Index of refraction curves for samples classified as mixed coal-tar creosotes (class 1).

of high and low boiling constituents. Their characteristic properties are as follows:

Class 1.—On a fractional distillation[2] the distillation curves fall within the lower shaded area shown in figure 5 (p. 15). The indices

[1] The classification has been slightly modified so that it will coincide with the definitions given in the first part of this publication. The third class, under mixed coal-tar creosotes, was not given in Circular 112.

[2] The method by which this distillation was made is described in the appendix.

of refraction at 60° C. of the fractions do not fall more than one in the third place of decimals below the upper shaded area in figure 6 (p. 16), and the specific gravities at 60° C. do not fall more than one in the third place of decimals below the lower limit shown in figure 4 (p. 14). On applying the sulphonation test to the fractions between

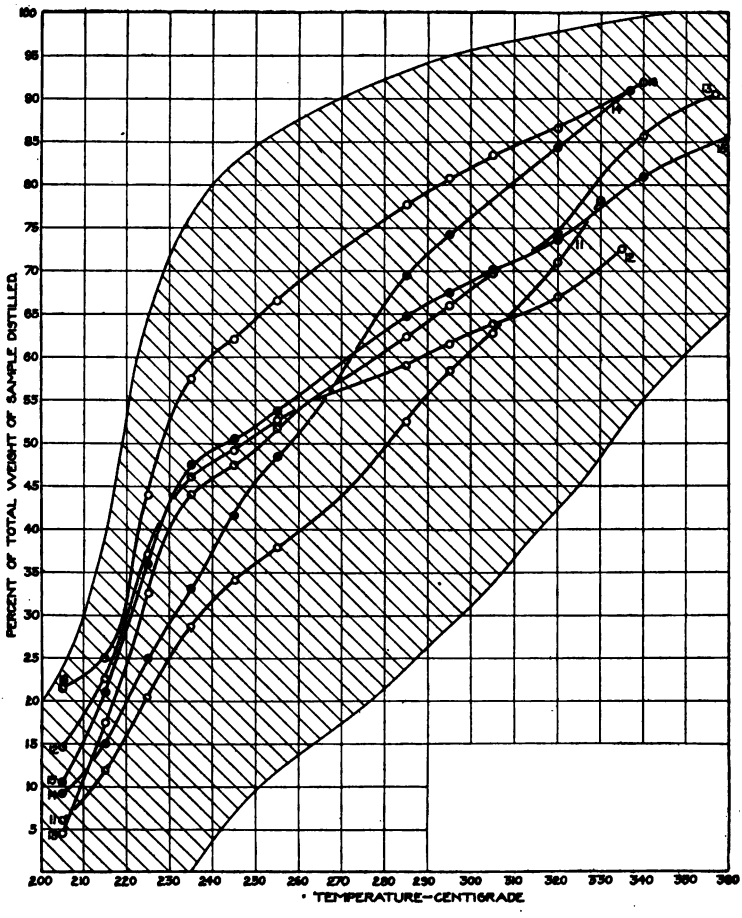

FIG. 9.—Fractional distillation curves for samples classified as mixed coal-tar creosotes (class 2).

305° and 320° C. there is no oily residue insoluble in caustic alkalies. The water does not exceed 1 per cent. There is no admixture of undistilled tar.

Class 2.—The percentage weights on distillation fall within the upper shaded area shown in figure 5. The specifications for index of refraction, specific gravity, and sulphonation test are the same as for

class No. 1. The water does not exceed 2 per cent. There is no admixture of undistilled tar.

Mixed coal-tar creosotes.

Mixed coal-tar creosotes are divided into three classes, according to the character and quantity of the admixtures.

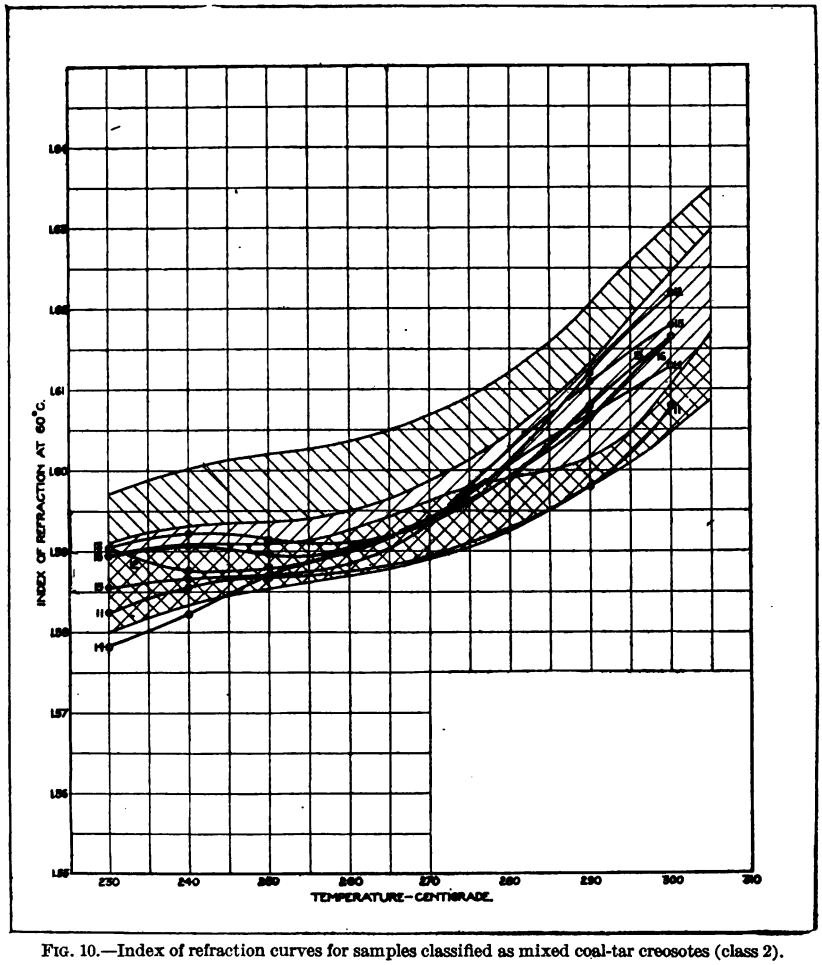

FIG. 10.—Index of refraction curves for samples classified as mixed coal-tar creosotes (class 2).

Class 1.—The presence of a certain amount of oil-tar creosote or products of a similar nature is admissible. The percentage weights on distillation fall within the shaded area shown in figure 7 (p. 17), and the indices of refraction fall within the middle shaded area shown in figure 8 (p. 18). The volume of the sulphonation resi-

due, in cubic centimeters, from the fractions, at from 305° to 320° C., is not greater than one-tenth of the weight of the fraction in grams. The water does not exceed 4 per cent. There is no admixture of undistilled tar.

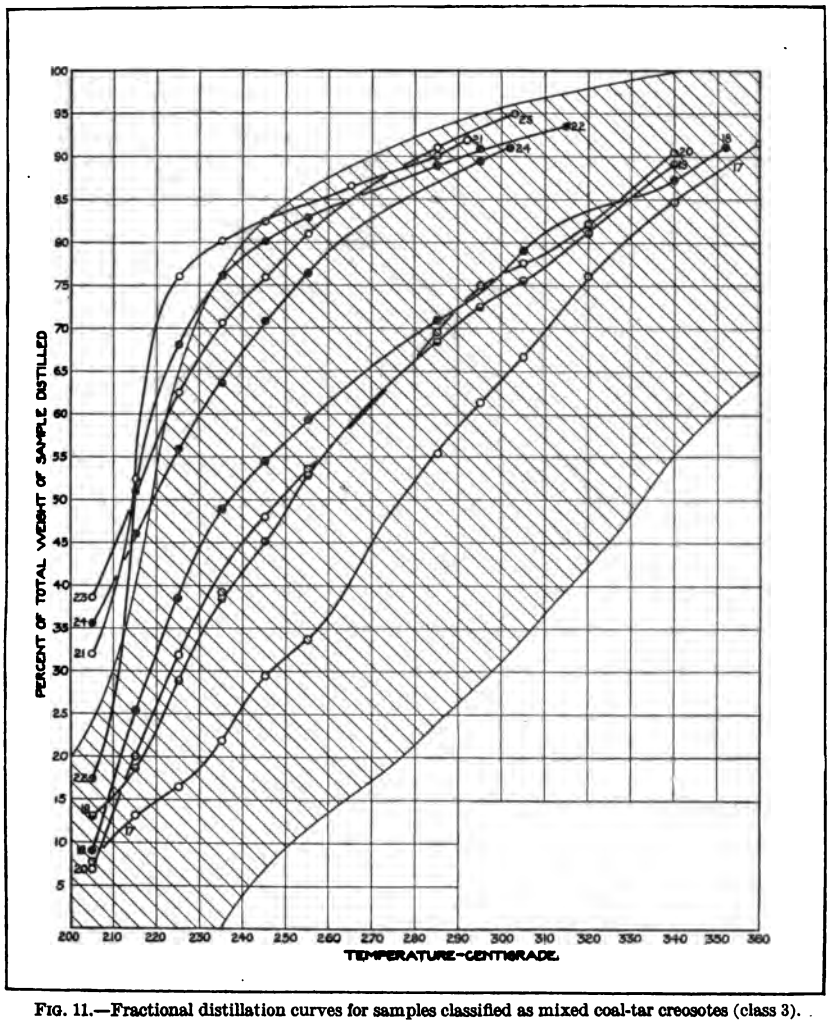

FIG. 11.—Fractional distillation curves for samples classified as mixed coal-tar creosotes (class 3).

Class 2.—Not only is the presence of certain quantities of oil-tar creosote or products of a similar nature admissible, but also adulterations with undistilled tar or other viscous material. The percentage weights on distillation fall within the shaded area shown in figure 9

(p. 19), and the indices of refraction fall within the lower shaded area shown in figure 10 (p. 20). The volume of the sulphonation residue, in cubic centimeters, from the fractions, at from 305° to 320° C., does not exceed one-fifth of the weight of the fraction in grams. The

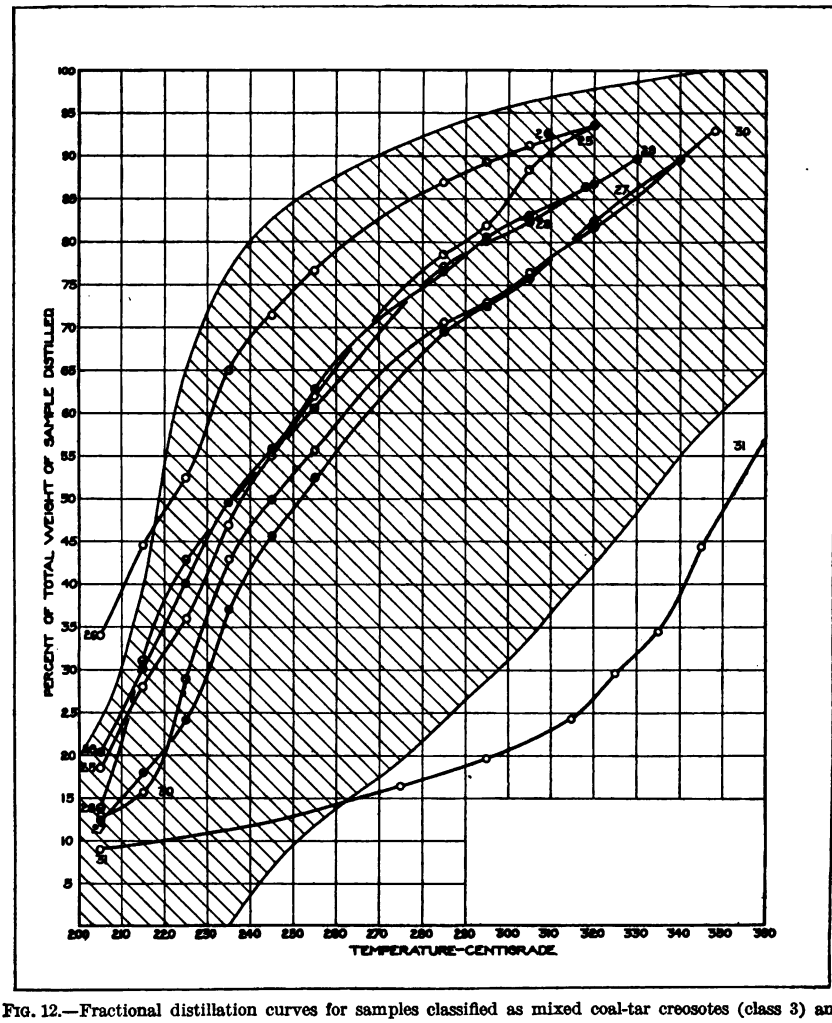

FIG. 12.—Fractional distillation curves for samples classified as mixed coal-tar creosotes (class 3) and water-gas-tar creosotes.

water in the creosote does not exceed 5 per cent, and admixture of undistilled tar or other viscous material does not exceed 15 per cent.

Class 3.—Mixed coal-tar creosotes which, on account of the quantity of paraffin constituents or undistilled tar or other viscous mate-

rial present, can not be classified in either of the foregoing classes are included in this class. The properties of such mixtures vary so greatly, according to the nature of the constituents, that they admit of no general description.

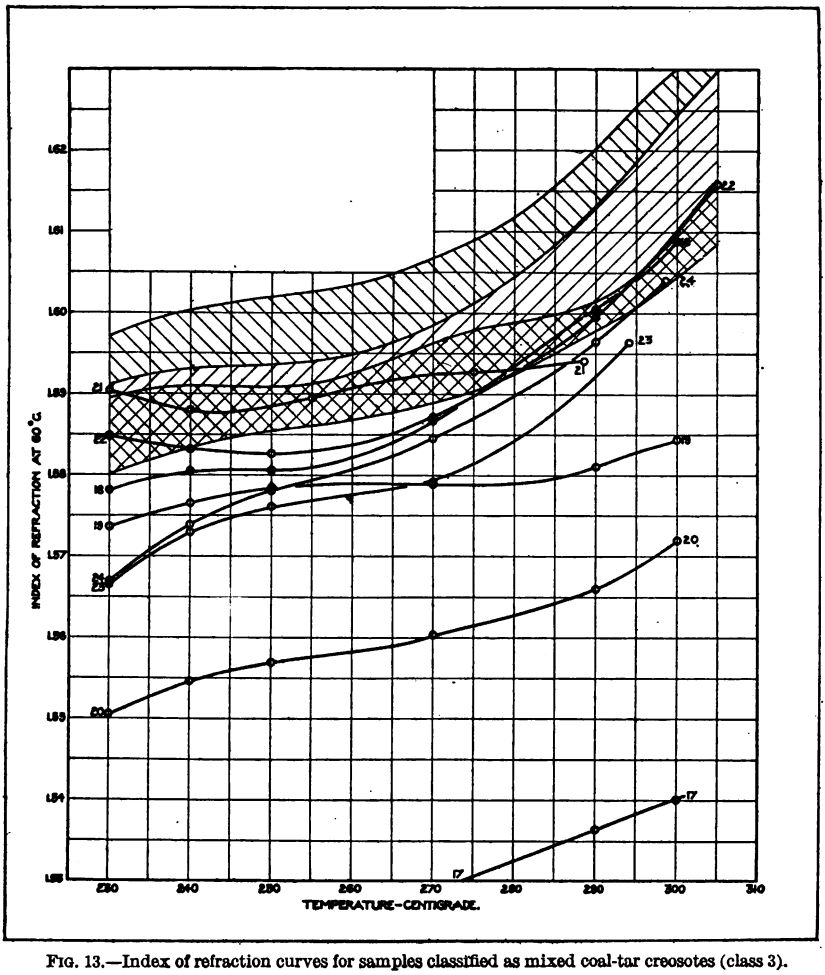

FIG. 13.—Index of refraction curves for samples classified as mixed coal-tar creosotes (class 3).

QUALITY OF COMMERCIAL CREOSOTES.

To secure authentic information on the quality and prices of available creosotes, the Forest Service, during 1909 and 1910, sought information and samples from a large number of dealers and manufacturers. In most cases these were supplied, and more than 70 per

cent of the firms responded to the request for samples for analysis. No wood-tar creosotes were included.

All of the samples received were analyzed and classified, so far as possible, in accordance with the method described. The data secured from each sample are given in detail in Table 1 and in figures 5 to 14,

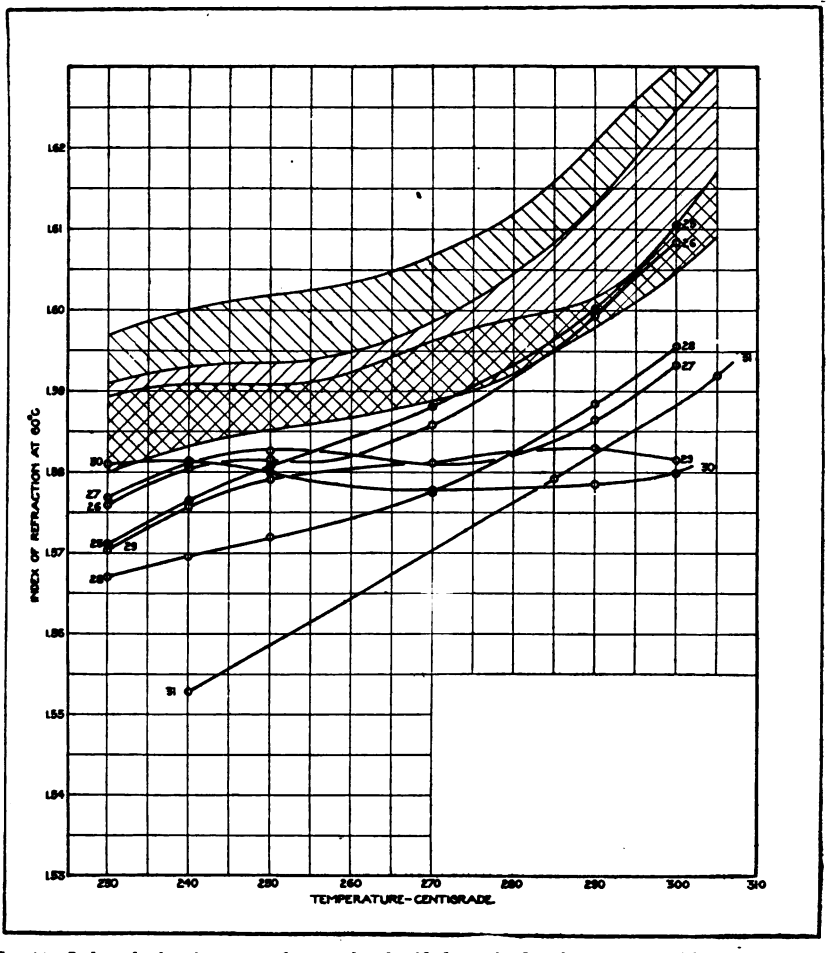

FIG. 14.—Index of refraction curves for samples classified as mixed coal-tar creosotes (class 3) and water-gas-tar creosotes.

inclusive. Although the method of examination is not entirely conclusive, all the samples were classified by the same method, and the results ought to give a fair comparison of the characteristics of the various samples.

TABLE 1.—*Classification and description of samples of commercial creosotes.*

Sample No.	Character of the oil.					Character of the fractions.			Character of residue.			Sulphonation residues of fractions, volume of residues (cubic centimeters) given in per cent of weight of fractions in grams.		
	Classification.	Color.	Odor.	Condition at room temperature.	Specific gravity at 60° C.	Distillation limits (°C.).	Color.	Condition at room temperature.	Temperature limits of distillation (°C.).	Color.	Condition.	Fraction 285°–295° C.	Fraction 295°–305° C.	Fraction 305°–320° C.
1	Coal-tar creosote, class 1.	Rich brown.	Not distinctive.	Viscous liquid.	1.1158	To 305	Reddish.	Liquid.	360	Dark brown.	Crystalline paste.	(1)	(1)	(1)
						305–320	Dark brown.	Paste.						
						320–340	Brown.	Solid.						
						340–360	do.	Viscous liquid.						
2	do.	Brown.	Like that of naphthalene.	Liquid.	1.0576	170–205	Pink.	Paste.	360	(2)	Viscous liquid	(1)	(1)	(1)
						205–225	do.	Solid.						
						225–235	Yellow.	Paste.						
						235–295	do.	Liquid.						
						295–320	do.	Solid.						
						320–360	Brown.	do.						
3	do.	Greenish brown.	Decidedly like that of naphthalene.	Partially solid.	1.0533	To 205	Yellow.	Liquid.	340	Brownish black.	Would not flow at 60° C.	(1)	(1)	(1)
						205–245	White.	Partially solid.						
						245–295	Yellow.	Liquid.						
						Above 295	Yellowish to yellow brown.	Partially solid.						
4	do.	Brown.	Not distinctive.	Liquid.	1.1118	205–245	White to yellow.	Solid.	360	do.	Clear liquid.	(1)	(1)	(1)
						245–305	Bright yellow.	Liquid.						
						305–340	Yellow.	Solid.						
						Above 340	Brown.	Liquid.						

[1] Too small to be regarded.

[2] Observation not recorded.

TABLE 1.—*Classification and description of samples of commercial creosotes*—Continued.

Sample No.	Character of the oil.					Character of the fractions.			Character of residue.			Sulphonation residues of fractions, volume of residues (cubic centimeters) given in per cent of weight of fractions in grams.		
	Classification.	Color.	Odor.	Condition at room temperature.	Specific gravity at 60° C.	Distillation limits (°C.).	Color.	Condition at room temperature.	Temperature limits of distillation (°C.).	Color.	Condition.	Fraction 285°–295° C.	Fraction 295°–305° C.	Fraction 305°–320° C.
5	Coal-tar creosote, class 2.	Brown.....	Decidedly like that of naphthalene.	Partially solid.	1.0305	To 170	Clear yellow.	Liquid....	320	Black.....	Crystalline paste.	(1)	(1)	(1)
						170–235	White to yellow.	Partially solid.						
						235–295	Yellowish green.	Liquid....						
						Above 295	Green to orange.	Partially solid.						
6	Mixed coal-tar creosote, class 1.	.....do.....	Like that of naphthalene.	Liquid....	1.0524	170–205	Yellow.....	Liquid....	350	(2)	(2)	3.90	3.10	1.40
						205–215	.....do.....	Paste.....						
						215–235	Yellowish	Solid.....						
						235–295	Greenish yellow.	Liquid....						
						295–305	.....do.....	Paste.....						
						305–320	.....do.....	Solid.....						
						320–350	Orange.....	Paste.....						
7	.....do.....	.....do.....	.....do.....	...do.....	1.0520	170–225	Straw color.	Liquid....	360	Black.....	Viscous liquid	7.00	3.90	1.80
						225–235	Yellow white or green.	Solid.....						
						235–295	Yellow green.	Liquid....						
						Above 295	Yellowish green to orange.	Partially solid.						
8	.....do.....	.....do.....	Decidedly like that of naphthalene.	...do.....	1.0303	205–235	White.....	Solid.....	338	Brownish black.	Soft paste....	.....	2.90	2.50
						235–305	Yellow.....	Partially liquid.						

					Above 305	Yellow green to brown green.	Solid.						
9	....do....	Rich brown.	Not distinctive....	...do....	1.0996	To 170	Yellow.....	Liquid....	360	(2)	Hard pitch...	None.	None.	2.70
						170–205	Red.....	Paste.....						
						205–235	Pink.....	Solid.....						
						235–255	Brown.....	Liquid....						
						255–305	Dark brown.	...do.....						
						305–340	Brownish yellow.	Solid.....						
						340–360	.....do.....	Liquid....						
10	.....do.....	Dark brown.	Like that of naphthalene.	...do.....	1.0512	To 170	.....	...do.....	340	Brownish black.	Stiff paste....	5.70	11.50	3.20
						170–245	White to yellow.	Partially solid.						
						245–285	Orange.....	Liquid....						
						Above 285	Green to orange.	Partially solid.						
11	Mixed coal-tar creosote, class 2.	Rich brown black.	.....do.....	Viscous liquid.	1.0676	To 215	Red.....	Liquid....	330	(2)	Soft.....	(2)	(2)	(2)
						215–225	Yellow.....	Solid.....						
						225–235	Yellowish brown.	...do.....						
						235–295	.....do.....	Liquid....						
						295–305	Green.....	Paste.....						
						305–320	.....do.....	Solid.....						
						320–330	Orange.....	...do.....						
12	.....do.....	Black.....	Decidedly like that of naphthalene.	...do.....	1.0747	205–235	Yellow white.	...do.....	335	Bright luster.	Medium hard pitch.	(1)	(1)	(1)
						235–285	Yellowish...	Liquid....						
						285–305	Brownish yellow.	Paste.....						
						305–335	.....do.....	Solid.....						
13	.....do.....	Brown.....	Like that of naphthalene.	Liquid....	1.0371	To 170	Clear.....	Liquid....	357	Brown.....	Paste.....	.....	.20	1.00
						170–205	Yellow.....	Paste.....						
						205–215	Pink.....	Solid.....						
						215–225	Red.....	...do.....						
						225–235	Brownish...	...do.....						
						235–245	.....do.....	Paste.....						
						245–295	.....do.....	Liquid....						
						295–305	Green.....	Paste.....						
						305–340	Greenish brown.	Solid.....						
						340–357	Orange brown.	Paste.....						
14	.....do.....	.....do.....	Not distinctive.....	...do.....	1.0371	To 305	White to reddish yellow.	Liquid....	337	.....do.....	Soft paste....	4.30	4.90	4.60
						305–337	Yellow.....	Solid.....						

[1] Too small to be regarded.

[2] Observation not recorded.

[3] No sulphonation tests.

TABLE 1.—*Classification and description of samples of commercial creosotes*—Continued.

Sample No.	Character of the oil.					Character of the fractions.			Character of residue.			Sulphonation residues of fractions, volume of residues (cubic centimeters) given in per cent of weight of fractions in grams.		
	Classification.	Color.	Odor.	Condition at room temperature.	Specific gravity at 60° C.	Distillation limits (°C.).	Color.	Condition at room temperature.	Temperature limits of distillation (°C.).	Color.	Condition.	Fraction 285°–295° C.	Fraction 295°–305° C.	Fraction 305°–320° C.
15	Mixed coal-tar creosote, class 2.	Black.....	Decidedly like that of naphthalene.	Liquid....	1.0514	205–235	White to yellow.	Solid.....	360	Black.....	Solid.....	10.10	7.40	.....
						235–285	Yellow.....	Liquid....						
						285–305	.....do.....	Paste.....						
						305–340	Yellow green	Solid.....						
						340–360	Orange red..	Paste.....						
16	.....do.....	Brownish black.	Like that of naphthalene.	...do.....	1.0167	205–235	Pink to yellowish.	Solid.....	340	Brownish black.	Soft paste....	6.20	2.30	4.20
						235–295	Yellow.....	Liquid....						
						295–305	Yellow green	Paste.....						
						305–340	.....do.....	Solid.....						
[1] 17	Mixed coal-tar creosote, class 3.	Brown.....	Like that of crude petroleum.	...do.....	.9657	170–360	Green to red.	Liquid....	360	Black.....	Viscous liquid.	(2)	(2)	(2)
18	.....do.....	.....do.....	Like that of naphthalene.	...do.....	1.0384	205–235	Yellowish...	Solid.....	340	Dark brown.	Viscous paste.	3.60	2.90	3.30
						235–245	.....do.....	Thin paste						
						245–295	Orange.....	Liquid....						
						295–350	Green.....	Solid.....						
19	.....do.....	Brownish black.	Like that of oil tar.	...do.....	.9944	170–225	Yellow.....	Liquid....	340	Brownish black.	Liquid.....	.....	1.60	4.60
						225–235	White.....	Thin paste						
						235–305	Green to orange green.	Liquid....						
						305–320	Green.....	Thin paste						
						320–340	.....do.....	Solid.....						
[1] 20	.....do.....	Brown.....	Like that of petroleum.	...do.....	.9852	170–305	Yellow green	Liquid....	340	Brown.....	.....do.....	(2)	(2)	(2)
						305–340	Green.....	Paste.....						
21	.....do.....	Brownish green.	Like that of naphthalene.	Half solid.	1.0092	170–205	.....	Liquid....	292	Black.....	Sticky paste.	(2)	(2)	(2)
						205–235	White to yellow.	Solid.....						

						235–292	Brownish yellow.	Liquid						
22	do	Brown	do	Solid		170–205	Yellow to red	do	315	do	Granular			[4] 3.50
						205–225	Yellow	Solid						
						225–235	Orange	Paste						
						235–295	Reddish brown.	Liquid						
						295–315	Yellow	Paste						
23	do	do	Not distinctive	Liquid	1.0000	To 285	Yellowish	Liquid	303	do	Sticky paste	[2]	[2]	[2]
						Above 285	Greenish yellow.	Solid						
24	do	Greenish brown.	do	do	.9929	170–302	Yellow	Clear liquid.	302	Brownish black.	do	[2]	[2]	[2]
25	do	do	do	do	1.0189	170–225	do	Liquid	320		Viscous liquid		7.50	
						225–245	do	Paste						
						245–295	do	Liquid						
						295–320	Yellow green	Solid						
26	do	do	do	do	1.0036	170–285	Yellow	Clear liquid.	320	Brownish black.	Does not flow	1.00	.30	.30
						285–295	Green	Paste						
						295–320	do	Solid						
27	do	Green	Like that of oil tar	do	1.0007	170–205	Yellow	Liquid	340	do	Liquid	[2]	[2]	[2]
						205–235	White	Paste						
						235–305	Yellow	Liquid				[2]	[2]	[2]
						305–340	do	Solid						
28	do	Greenish brown.	Not distinctive	do	1.0123	170–305	do	Liquid	305	Dark brown	Soft paste			
						305–318	Yellow green	Partially solid.						
29	do	Brown	do	do	1.0175	To 170	White	Liquid	330	Brownish black.	Sticky paste	[2]	[2]	[2]
						170–225	Yellowish green.	do						
						225–235	Yellow	Paste						
						235–295	Green	Liquid						
						295–330	do	Solid						
30	Water-gas-tar creosote.	Greenish brown.	Like that of oil tar	do	1.0040	170–205	Yellow	Liquid	348	Black	Viscous liquid		6.90	3.50
						205–215	White	Paste						
						215–225	do	Solid						
						225–235	do	Paste						
						235–295	Yellow	Liquid						
						295–320	do	Paste						
						320–348	do	Solid						
31	do	Reddish green.	Like that of kerosene.	Mobile (?) liquid.	1.0580	185–295	Light brown	Liquid	378	Dark brown	Liquid	[2]	[2]	[2]
						295–378	Yellow	do						

[1] Tar-acid contents of fraction from sample No. 17: 170°–245° C., very high in tar acids; 245°–255° C., 22 per cent; 255°–285° C., 16.7 per cent.
[2] No sulphonation tests.
[3] Tar-acid contents of fractions from sample No. 20: 170°–205° C., 1.5 per cent; 205°–215° C., 7.2 per cent; 215°–225° C., 7.2 per cent; 225°–235° C., 2.7 per cent; 235°–245° C., 3.4 per cent; 245°–255° C., 1.2 per cent; 255°–285° C., 0 per cent; 285°–295° C., 0.6 per cent; 295°–305° C., 0.4 per cent.
[4] For fraction 295°–315°.

The reason for putting each creosote in the particular class to which it is assigned will, in most cases, be apparent, but the following explanations are required as to certain of the samples:

Sample No. 1.—Although the index of refraction values of sample 1 fall practically within the limits assigned to coal-tar creosotes, the distillation curve falls somewhat below the limits assigned to such creosotes. The analysis seems to indicate that, although the sample was a coal-tar creosote, some of the lower-boiling constituents had been removed.

Sample No. 4.—The index of refraction values for the higher fractions of sample 4 have a tendency to fall below the limits assigned to coal-tar creosotes, which indicates that the sample may have contained a small admixture of a high-boiling petroleum substance. The distillation curve indicates that, as with sample 1, some of the lower-boiling constituents had been removed.

Samples Nos. 17 and 20.—The low index of refraction values of samples 17 and 20, in conjunction with the high tar-acid content of some of the fractions, indicate that these samples were from creosotes produced from blast-furnace tar.

Samples Nos. 30 and 31.—Samples 30 and 31 were known to be from creosotes produced from water-gas tar; their fractional distillation and indices of refraction are plotted in conjunction with the mixed coal-tar creosotes merely for convenience in comparison.

Samples Nos. 27, 28, and 29.—The similarity of the index of refraction values of samples 27, 28, and 29 to those of samples 30 and 31 leads to the belief that they also were water-gas-tar creosotes.

Table 2 is a classified summary, by regions of supply. It is interesting to note that of 31 samples of creosote received from all parts of the country, only 5 samples, or less than 17 per cent, could be classified as coal-tar creosotes, while approximately 80 per cent were graded as mixed coal-tar creosotes. The 2 remaining samples were known to have been produced from water-gas tar. Of the 5 samples graded as coal-tar creosotes, 2 were supplied from the East, 2 from the South, and 1 from the Middle West.

TABLE 2.—*Classification of samples of commercial creosotes.*

[Actual number and per cent of total falling in each class.]

Region.	Number of firms which submitted samples.	Number of samples submitted.	Coal-tar creosotes.						Mixed coal-tar creosotes.									Water-gas-tar creosotes.		
			Class 1.			Class 2.			Class 1.			Class 2.			Class 3.					
			Sample No.	Number.	Per cent.	Sample No.	Number.	Per cent.	Sample No.	Number.	Per cent.	Sample No.	Number.	Per cent.	Sample No.	Number.	Per cent.	Sample No.	Number.	Per cent.
Eastern States	7	10	3	1	10	5	1	10	.....	0	0	12	1	10	19, 20, 21, 26, 27	5	50	30, 31	2	20
Southern States	6	11	1, 2	2	18.2	.....	0	0	6, 7, 9, 10	4	36.4	11, 13, 15	3	27.2	17, 18	2	18.2	.....	0	0
Middle Western States	5	5	4	1	20	.....	0	0	8	1	20	16	1	20	22, 23	2	40	.....	0	0
States west of the Mississippi River	5	5	.....	0	0	.....	0	0	.....	0	0	14	1	20	24, 25, 28, 29	4	80	.....	0	0
Total	.....	31	.....	4	13	.....	1	3	.....	5	16	.....	6	19	.....	13	42	.....	2	7

PRICES AND CONSUMPTION.

The quoted prices per gallon f. o. b. works are summarized in Table 3. It is only fair to state that the high quotations in the maximum columns under "Middle Western States" were all received from one firm and apply to what is said to be a special grade of oil. It is unfair, therefore, to compare these quotations with the others and the next high quotations have been inserted in brackets in these columns.

A comparison of the individual figures reveals the fact that in all sections of the country the price for small lots is considerably in excess of that for large orders or tank-car lots; increase in individual cases varies from 25 to 200 per cent. In practically all cases the quotations from the Eastern States were lower than for the other sections. In general they differed but slightly from the quotations from the Southern and Middle West sections, yet there is a decided difference when compared to the States west of the Mississippi River. The low minimum quotations for tank-car lots in the States west of the Mississippi River apply to the Pacific coast; in the Rocky Mountain region higher prices prevail as a result of the heavy freight charges on creosote shipped to these points.

Similar statistics were not collected for wood-tar creosotes, but the price for small orders is likely to be from 40 to 60 cents per gallon. It is possible that in large quantities wood-tar creosote may be secured at a considerably lower figure.

TABLE 3.—*Prices of commercial creosotes.*

Region.	Number of firms addressed.	Price per gallon f. o. b. works, including package.								
		1-barrel orders.			60-barrel orders.			Tank-car lots.		
		Number of quotations.	Maximum.	Minimum.	Number of quotations.	Maximum.	Minimum.	Number of quotations.	Maximum.	Minimum.
			Cents.	*Cents.*		*Cents.*	*Cents.*		*Cents.*	*Cents.*
Eastern States	13	5	15	7	5	12	7.5	5	12	5.5
Southern States	9	5	20	9	3	16	12	6	12	6.7
Middle Western States	7	4	[1] 60 [20]	12	3	[1] 40 [12]	10	4	[1] 40 [9]	5.5
States west of the Mississippi River	7	5	25	20	4	19	16	4	15	[2] 6.7

[1] These figures apply to what is said to be a special grade of oil. Figures in brackets are next highest quotations received.

[2] This low quotation is from a firm on the Pacific coast, and applies to an imported product.

Statistics of the consumption of commercial creosotes do not as a rule distinguish between coal-tar creosotes and other closely allied products. However, coal-tar creosotes, either pure or more or less mixed with other products, make up the bulk of the consumption, and the figures given in Table 4 may therefore be taken to represent the approximate quantity of these creosotes used. It is probable that a small amount of oil-tar creosote also is included in the figures.

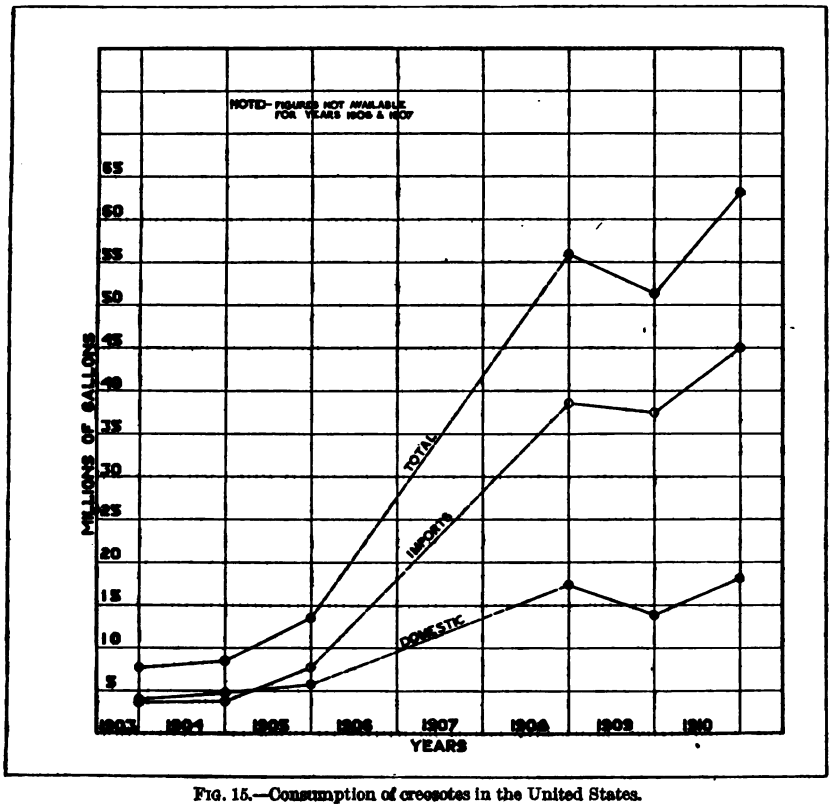

FIG. 15.—Consumption of creosotes in the United States.

The statistics are represented diagrammatically in figure 15, which shows the strikingly rapid increase in the consumption of creosote, as well as the relatively small quantity produced in this country. In 1903 and 1904 the domestic production exceeded the imports, but since that time, although the annual consumption of domestic creosote has practically quadrupled, the imports have rapidly outstripped the domestic production, and in 1910 exceeded it by almost 150 per cent.

TABLE 4.—*Consumption of creosotes.*

Year.	Domestic.	Imported.	Total.
	Gallons.	*Gallons.*	*Gallons.*
1903 [1]	4,000,000	3,711,565	7,711,565
1904 [1]	4,850,000	3,783,472	8,633,472
1905 [1]	5,800,000	7,750,531	13,550,531
1908 [2]	17,360,000	38,640,000	56,000,000
1909 [2]	13,862,171	37,569,041	51,431,212
1910 [2]	18,184,355	45,081,916	63,266,271

[1] The figures for 1903, 1904, and 1905 were taken from Forest Service Circular 98, and apply to coal-tar creosote. The domestic supply figures are from estimates by Prof. Gellert Alleman. Imports are from the annual reports of the Department of Commerce and Labor.

[2] The figures for 1908, 1909, and 1910 are from Forest Service Circular 185 and were compiled from reports on the consumption of creosote received from more than 90 per cent of the treating plants in operation during these years.

No figures are available for 1906 and 1907.

It is not difficult to find the reason for this condition. In Europe the refinement of coal tar is conducted largely for the production of coal-tar dyes, and this does not interfere with the production of a good grade of creosote. On the other hand, in the United States where the prime object is the production of pitch, the only creosote produced is that which will not interfere with the character or amount of the pitch. Furthermore, by-product retorts are more extensively used throughout Europe than in this country, where large quantities of coal are coked in the beehive ovens with a loss of the possible by-products.

There is no reason to doubt that more than enough creosote might be produced in the United States to supply the present demand. Statistics published by the Geological Survey [1] show that in 1909 practically 60,000,000 gallons of tar were produced in the manufacture of coke in by-product coke ovens, and although no statistics are at hand showing the tar produced at the gas-house plants for that year the total production of gas-house tar in 1907 and 1908 was greater than that from the by-product coke ovens. It is safe to assume, therefore, that the total amount of coal-tar produced in 1909 was at least 100,000,000 gallons. Assuming that 5 gallons of tar will produce 1 gallon of creosote, the total amount of coal-tar creosote which might have been produced is approximately 20,000,000 gallons, or about 50 per cent more than the domestic creosote consumed that year. This possible production could be further vastly increased by the wider use of the by-product retorts. The average yield of tar from the bituminous coal coked in the by-product ovens in 1909 was 6.4 gallons per short ton; the approximate quantity of bituminous coal coked in the bee-hive ovens during that year was 51,000,000 short tons. Had this coal been coked in by-product ovens, approximately 326,000,000 gallons of tar might have been produced, or an

[1] All statistics quoted from the Geological Survey are taken from the following publications: The Manufacture of Coke in 1909, by Edward W. Parker, and Production of Gas, Coke, Tar, and Ammonia at Gas Works and in Retort Coke Ovens, and of Gas and Tar at Water-Gas Works, by the same author.

amount sufficient to provide more than 65,000,000 gallons of coal-tar creosote. This amount exceeds the total consumption for that year by more than 13,500,000 gallons.

The Geological Survey reports the production of 9,168,834 gallons of oil and water-gas tars in 1908, but the report states that "most of the tar is used for fuel at the works, no record being kept of the output." Substantiating this theory, it is then stated that "in addition to the amount above listed over 5,500,000 gallons were reported in 1908 as made and not sold." Only recently has oil-tar creosote been marketed under that name. Statistics of the production or consumption are not available, but it is undoubtedly much in excess of the figures given.

Wood-tar creosotes do not at present rank in importance with the coal-tar creosotes. Although the quantity of wood tar produced in 1909 was approximately 20,000,000 [1] gallons, an amount capable of yielding approximately 2,000,000 gallons of creosote, a large portion of this tar was consumed as fuel, and the quantity of wood-tar creosote actually produced was much less than the possible production.

[1] This figure is estimated from statistics published by the Bureau of the Census in Wood Distillation, 1909.

APPENDIX.

METHOD USED IN ANALYZING THE CREOSOTES DISCUSSED IN THIS PUBLICATION.[1]

[NOTE.—All temperatures referred to in the following are on the centigrade scale.]

Specific gravity of the whole oil.

The perfectly liquefied oil is poured into a hydrometer cylinder, and, at a temperature of 60°, the specific gravity is read with hydrometer standardized against water at 60°.

The somewhat prevalent method of determining specific gravity with a hydrometer standardized at 15° and then calculating the results from the temperature of the determination back to 15° is roundabout and involves the expression of the specific gravity of creosote in the liquid condition at a temperature at which the oil does not exist as a liquid. The method is illogical and open to inaccuracies. With very rare exceptions creosotes are all liquid at 60°, and if the weight of a unit volume of the oil at 60° is compared with the weight of a unit volume of water at 60°, a true specific gravity is obtained. * * *

Fractional distillation.

The Hempel distilling flask of resistance glass, shown in figure 16, is employed. The empty flask is tared, 250 grams of melted, well-shaken oil introduced, the platinum-wire plug and the glass beads put in place, and a second weight taken. The thermometer is then inserted in the flask, so that the first emergent reading is 200°.[2]

[1] Condensed and reprinted from Forest Service Circular 112.

[2] In the distillations and analyses described in this publication, one thermometer standardized by the Bureau of Standards was used throughout and was in all cases inserted in the Hempel flask so that the bulb was opposite the outlet tube. The temperatures actually recorded by the thermometer were used in plotting the distillation curves and limits of the different classes of creosote. Corrections for the emergent stem of the thermometer were not made, as, using the same thermometer placed in the same position, the results will be constant within the limits of error in the methods employed. However, should it be desired to compare the analyses given in this publication with the analyses of other creosotes similarly distilled, using a standardized thermometer but calibrated to a different scale, so that the first emergent reading is not 200° C., the temperatures should be corrected in both cases. The correction to be added to the observed temperatures can be determined by the following formula:

$$\text{Correction} = 0.00016(T - t)N,$$

where

T=thermometer reading.

t=temperature of emergent stem.

N=number of degrees of the thermometer reading which are emergent.

The following table gives the corrections which should be used for the results in this publication:

TABLE 1.—*Corrections for the emergent thermometer stem.*

Temperature reading.	Corrected reading.	Temperature reading.	Corrected reading.
°	°	°	°
170	170	250	251.6
180	180	260	262
190	190	270	272.4
200	200	280	282.9
210	210.3	290	293.4
220	220.6	300	303.9
230	230.9	310	314.4
240	241.2	320	325

The flask is supported on an asbestos board with a slightly irregular opening of very nearly the largest diameter of the flask. A condensing tube is employed and the fractions are collected in tared flasks. The distillation is run at the rate of 1 drop per second, and fractions collected between the following temperatures: Up to 170°, 170°–205°, 205°–225°, 225°–235°, 235°–245°, 245°–255°, 255°–285°, 285°–295°, 295°–305°, 305°–320°, and if feasible, 320°–360°.

The character of the fractions and their weights are recorded and the results plotted as a curve, in which the ordinates are percentages by weight and the abscissæ temperatures. * * * When the distillation has reached the 225° point, an asbestos-board box should be placed around the distilling flask, to cover the bulb, but leave the Hempel column exposed. Drafts upon the distilling apparatus must be avoided.

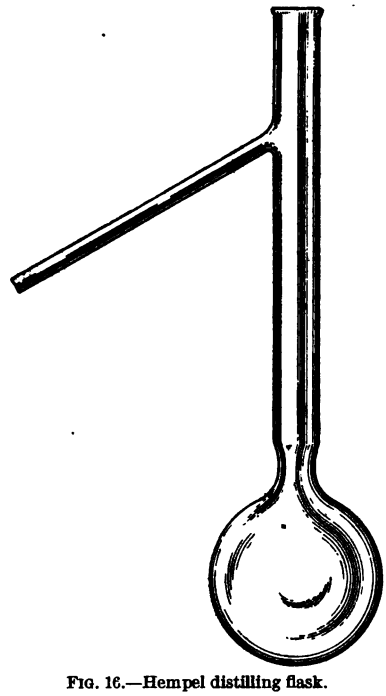

FIG. 16.—Hempel distilling flask.

Index of refraction.[1]

The indices of refraction of the different fractions between 235° and 305° are determined at 60° in a refractometer with light compensation. The results are plotted with temperatures as abscissæ and indices of refraction as ordinates.

Specific gravity.

The specific gravities of the fractions between 235° and 305° are determined by means of specific-gravity bottles. These bottles are filled at 60° and the weights referred to water at the same temperature. The results are plotted as a curve, in which the ordinates are specific gravities at 60° and the abscissæ temperatures.

[1] The following explanation of the index of refraction and of the sulphonation test is also taken from Forest Service Circular 112:

"INDEX OF REFRACTION.

"The index of refraction is the ratio between the sines of the angles of incidence and of refraction of light, expressed by the formula $\frac{n}{D}=\frac{\text{sine I}}{\text{sine R}}$, where $\frac{n}{D}$ means the index of refraction referred to sodium light, I equals the angle of incidence, and R the angle of refraction. The index of refraction varies with the temperature, but is constant for any given oil at a stated temperature. In making measurements of the index of refraction of the different fractions of a creosote distillation, it was necessary to make the measurements at 60°. The determinations were made with an Abbe refractometer provided with a light compensator. By means of this instrument the index of refraction may be read with great accuracy, and the measurement is one of the most exact which can be applied to such an oil."

"SULPHONATION TEST.

"In contradistinction to the hydrocarbons of the paraffin series, those of the aromatic series react with concentrated sulphuric acid with marked ease. The products of this reaction, in which a sulpho group or groups replace hydrogen in the aromatic compound, are called sulphonic acids and the process is known as sulphonation. For example, the reaction with benzene would be $C_6H_6+H_2SO_4=C_6H_5SO_3H+H_2O$. The sulphonic acids are characterized by their solubility in water. If a fraction from the distillation of a creosote oil be treated under proper conditions with concentrated sulphuric acid, it will be converted into a mixture of sulphonic acids, which will readily dissolve in water. If, however, there are paraffin bodies present they will not be attacked to the same degree as the aromatic hydrocarbons, and when the products of the sulphonation are treated with water the paraffin components will remain as a residual oil. In applying this test to creosote oils it has been found that the most information is obtained by using it on the higher-boiling fractions."

Sulphonation test.

The fraction distilling between 305° and 320° is treated with concentrated sulphuric acid and poured into a separatory funnel such as is shown in figure 17. The flask which contained the fraction is rinsed out twice more with concentrated sulphuric acid and the rinsings added to the funnel. Enough more concentrated sulphuric acid is added nearly to fill the funnel, and the mixture is thoroughly shaken at least six times in 30 minutes. After standing until it becomes cool the volume is brought up into the graduations by the addition of concentrated sulphuric acid, and after another hour the amount of unsulphonated oil is read and the percentage calculated. The residual oil is usually almost white or a pale blue. In some cases a reddish oil with a distinctive odor is obtained from a pure coal-tar creosote; this oil does not consist of hydrocarbons and is soluble in caustic alkalies. The sulphuric acid should therefore be drawn off, the oil washed with water, and a 10 per cent solution of sodium hydroxide added. If the oil is soluble in this reagent, the sulphonation test is regarded as negative.[1]

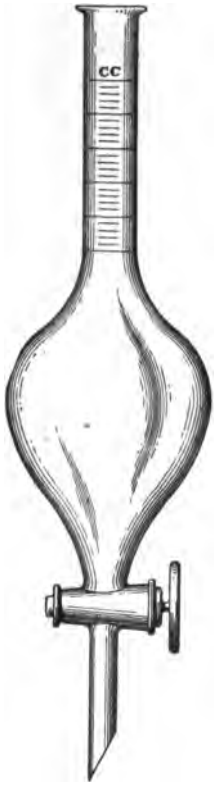

FIG. 17.—Separatory funnel for sulphonation test.

Tar acids.

Fifty cubic centimeters of the creosote under analysis are measured at 60° into a small distilling flask by a pipette. The oil is distilled as completely as possible without breaking the distilling bulb, and the distillate is caught in a short-stemmed, 100 cubic centimeter separating funnel. At the end of the distillation 25 cubic centimeters of boiling hot 15 per cent sodium hydroxide is added to the distillate and the mixture thoroughly shaken. The alkaline extract is then drawn off into a 100 cubic centimeter shaking cylinder and 25 cubic centimeters more of hot sodium hydroxide added. After extracting with this second portion for five minutes, with frequent shaking, the solutions are allowed to separate and the alkaline extract added to the first portion in the cylinder. A third extraction is made with 15 cubic centimeters of alkali. The total alkaline extract is cooled, acidified with sulphuric acid, thoroughly shaken, brought to 60°, and the volume of supernatant oil read off.

Water.

After weighing the first two fractions of a fractional distillation they are united in a small separatory funnel and any water which is present is separated from the oil and its amount accurately determined. If particular accuracy is required in the estimation of the water it may be done by the Marcusson xylol distillation method.[2]

[1] More recent investigations have led to a modification of this method; described in Forest Service Circular 190, by Ernest Bateman.

[2] Forest Service Circular 134, The Estimation of Moisture in Creosoted Wood.

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THE PROFESSION OF FORESTRY.

RAPID DEVELOPMENT OF FORESTRY IN THE UNITED STATES.

During the last decade forestry in the United States has developed with remarkable rapidity. The inauguration of forest management on the National Forests, the activity of various States in public forestry, and the increasing interest of private owners in timber growing and protection have resulted in a marked demand for trained foresters.

When active work in forestry first began there were no forest schools in the country, and those entering upon the work were obliged to go to Europe for technical training. In anticipation of the need for foresters, and in order to aid in the development of forestry, several progressive institutions established schools of forestry even before the demand for any considerable number of men was definitely assured.

The first professional school was established at Cornell University in 1898. This was followed in 1900 by the Yale Forest School. Private instruction in forestry was given at Biltmore, North Carolina, by Doctor Schenck in connection with his work on the Vanderbilt estate as early as 1897, and a school for rangers was started by the State of Pennsylvania at Mont Alto, Pennsylvania, in 1903. Since that time instruction in forestry has been introduced in a large number of institutions. To-day there are 22 institutions which give courses leading to a degree in forestry, and about 40 others which include forestry in their curricula. It is estimated that there are fully 500 men in the United States with a greater or less degree of technical training, in addition to 1,500 forest rangers who began without a knowledge of the technical side of forestry, but many of whom through their experience in National and State forest work under technical direction have acquired considerable knowledge of certain phases of the subject. There are probably about 1,000 young men studying in the forest schools.

Forestry may therefore be considered an established profession in the United States. Hundreds of young men are considering it as a life vocation, and are eager to be informed regarding the character of work involved, the elements necessary for success, the requirements for an adequate training, the present and probable future opportunities for work, and its possibilities as a means of livelihood.

FORESTRY AS A VOCATION.

LIFE OF THE FORESTER.

Although forestry is now a recognized profession, perhaps a majority of the people in this country still have only a vague idea as to the kind of life the forester really leads. Many young men are attracted to it because it is an outdoor profession. They are fond of camping in the woods, of fishing, and of hunting, and the prospect of being able to spend a part of each year in the woods in connection with their regular work seems very alluring. Such men should remember, however, that the forester in his field work is seldom able to enjoy the comforts to which the ordinary sportsman is accustomed, and that spending considerable time in the woods as part of one's regular business is very different from camping out for a few weeks on a vacation.

Any one who plans to take up forestry should realize at the outset that his work is to be principally in the woods, often under trying conditions. This is particularly true during the early days of his work, when he is serving his apprenticeship, and as the number of foresters increases and competition becomes more intense, this period may be expected to lengthen. The young forester is also apt to have his headquarters shifted frequently from place to place, as is the case with civil engineers, so that he may be unable for some time to establish a home.

On the other hand, if he is an able man, he will ultimately be advanced to a position of responsibility which will give him more permanent headquarters and a greater opportunity for home life. Even in the higher positions, however, whether in government or in private work, the forester will be obliged to spend a great deal of time in supervising the actual woods operations on the ground. In the aggregate he will usually spend from 40 to 60 per cent of his time in the field, mainly on short trips of from one to six weeks, and the rest of his time in the office. His home will ordinarily be in a small town or its vicinity, with but little opportunity for city life. Even here he must not count himself secure against a change of working field which will necessitate removal to a new place.

To one who enjoys a life of this sort, the profession is fascinating; to one who does not, the work soon becomes monotonous and even positively disagreeable.

The character of work which the forester is called upon to do varies greatly under different conditions. Some men spend the greater part of their time in the more strictly technical work of the profession. They study such problems as the determination of the amount of merchantable timber on a given tract, its rate of growth, the best methods of cutting to secure a second crop without recourse

to planting, and, in general, all problems which deal with the life history and production of the forest. Other men spend more time on the business end of the profession, in devising methods of protecting the forest from fire, in organizing an efficient system of administration, in determining the cheapest and most effective methods of lumbering, and, in general, in dealing with the problem of the utilization of the forest.

By far the greater number of foresters, however, have to deal with both the scientific and the business aspects of the profession. They must know how to appraise the value of timber and how to utilize it in the best possible way, as well as how to grow it. They must be able to estimate how much it will cost a thousand feet to log a given tract of timber, at the same time that they predict how soon it will be profitable to cut the same area again. In other words, the average forester must be a good business man, with a thorough technical education. The scientific equipment is simply a matter of thorough schooling; the business equipment must be secured by practical experience in woods work.

Many of the men who prepare for forestry should anticipate employment with lumber companies. This will usually require several years of hard work in the woods, in logging camps, or at the mill, in relatively subordinate positions, to learn the practical details of the business. This apprenticeship is essential before responsible or attractive positions can be secured, and indeed before a forester can apply technical methods of management to the business intelligently, or can acquire the confidence of his employers so that his recommendations will be followed.

REQUISITES FOR SUCCESS.

The first requisites for the successful forester are that he have a liking for the sort of life which he will have to lead, and that he possess the health and constitution to stand it. The forester's work is physically exacting. He has to make long, hard trips in the forest, and under present conditions and those which will continue for a long time to come travel is necessarily rough. Sometimes it means a long trip on horseback, sometimes by canoe, and sometimes very hard and rough walking. The forester is not infrequently subject to actual physical hardships, and in any event he must have the constitution to endure such hardships should the occasion arise.

It must not be understood from this, however, that the profession is a muscular one, pure and simple. It requires brains, and brains of a high order, particularly at the present stage of the profession in this country, when nearly every forester is doing distinctly constructive work. The successful forester must have to a large degree the qualities of foresight and broad-mindedness, and these must be sup-

plemented more and more, as the work becomes better organized, by a thoroughness in details. The man who is capable only of carrying out some one else's plans will always remain an assistant.

Another prime requisite for the forester is administrative and executive ability. His work is extremely practical, and is either directly or indirectly concerned with the practical business administration of property. As soon as he passes beyond the state of being a mere assistant he has charge of men, and to be successful must have the ability to understand and to manage them. This applies particularly, of course, to men engaged in administrative work, as are most of the foresters in this country at present. Even in strictly investigative work, however, where the forester has no direct administrative responsibility, he is doing work which is essential for the proper handling of the forest, and must be thoroughly practical if his investigations are to be of value in securing better methods of forest management.

In addition to executive ability many foresters must have those qualities which go to make up a public teacher. Nearly every forester, whether consciously or not, is helping to mold public sentiment, and in many positions educational work is a part of his regular duties. This is often the case with the first work of a State forester, who must be able to present his message by public addresses and public writings. This requires a certain amount of address and confidence, and the ability to formulate concise and effective arguments.

One of the most important requisites for success, particularly in this country, is the spirit of public service. The conservation of our natural resources is the greatest internal problem before the country to-day, and forestry touches the conservation of all our natural resources. Every forester is doing a work which directly benefits the public. It has been a difficult task to accomplish what has already been done in forestry. It will be a still more difficult one to carry the work to completion. The public forester has many obstacles to overcome, and his financial returns are small; but his opportunities for public service are correspondingly great. His reward ought to be very largely in the satisfaction of doing a constructive work which profoundly affects the prosperity of his country. It is this spirit of public service which is keeping in Government forest work to-day men who are repeatedly refusing offers of private work with much higher salaries than they are receiving from the public.

A final requisite for success in forestry, as in any other profession, and one which can not be overestimated, is a fundamental and thorough training for the work. As the number of foresters in the country steadily increases, and competition becomes more keen, the necessity for a thorough education will grow more and more urgent.

NECESSARY TRAINING.

The thoroughly trained technical forester should have an education equivalent to that of any other well trained professional man, such as a lawyer, or doctor, or civil engineer. Such an education can not ordinarily be obtained in less than four years of college work. A course of five or six years, one or two of which are spent in post-graduate work, is still better. There is now a great abundance of well equipped forest schools in this country, offering both under-graduate and post-graduate work, and the average man can not hope to be successful in the profession without a complete course in one of these schools. The more practical field experience he can secure in addition to this, the better prepared he will be. For the large number of men who will look for employment to the lumbering business or other forest-using industries a thorough training in the principles of forestry, through four or five years of college work, is as necessary as in the case of men who plan to specialize upon the more scientific and technical sides of the profession. Such training, however, is but one part of the needed equipment. It must be supplemented by first-hand experience in lumbering operations.

While post-graduate work in Europe is not essential, it is a valuable asset to the man who can avail himself of it. Conditions here are so different from those in Europe that many of the methods commonly used there are wholly impracticable in this country. At the same time the profession has become so thoroughly established and has accomplished so much there that a careful study of European forestry can not fail to be suggestive and of much practical value to the American forester.

Closely allied with work in technical forestry is that of the forest ranger. The ranger will not be called upon to do such technical work as the professional forester, and does not need so much schooling. His work is of an exceedingly practical nature, and if he can work under some instruction he can pick up a great deal of the empirical knowledge which he needs along technical lines. Most forest rangers to-day have received their early training through long experience in the woods. Such experience is essential for the efficient ranger, but in addition it is extremely desirable for him to have a practical course at some ranger school. His usefulness and his chances for promotion are greatly increased if he can spend even two or three months taking such a course, for example, as that now given at a number of our western universities. Up to this time educational institutions have devoted much less attention to training rangers than to training technical foresters. At present only a few ranger courses are given in the entire country, and these are more in the nature of short courses than a full ranger training. Better facilities for obtaining the education needed

by a ranger will undoubtedly become available in the near future. A well-rounded ranger course should cover a period of about one full year, and should be conducted primarily in the field along very practical lines.

THE FIELD OF WORK.

Foresters are now finding employment with the Federal Government, with various States, with lumbermen and other private owners of timberland, and with educational institutions and those conducting research in forestry.

GOVERNMENT WORK.

So far the United States Government has been the principal employer of foresters. It is probable that fully 95 per cent of the trained foresters in the country have at one time or another been engaged in Government work, and 60 per cent or more are in it to-day. There is a small group of foresters in the Indian Office in the Department of the Interior, who are in charge of the forests owned by the various Indian tribes, and more foresters will undoubtedly be employed by the Department of the Interior when the National Parks are placed under technical administration. At present, however, nearly all of the forestry work of the Federal Government is conducted by the Forest Service in the Department of Agriculture. The work of the Forest Service may be divided into two parts: First, the administration and protection of the National Forests; and, second, technical investigations and cooperation with States and private owners.

ADMINISTRATION AND PROTECTION OF NATIONAL FORESTS.

The National Forests cover a gross area of nearly 190,000,000 acres, situated chiefly in the mountains of the West. The administration and protection of this vast domain constitutes the greatest task of the Forest Service, and occupies the time of most of its men. The administration of the National Forests is centered in the Washington office, to which are attached certain higher officers engaged in general direction and inspection of the work. For convenience in field administration there have been established six National Forest districts, each in charge of a District Forester, who has associated with him such technical assistants as are necessary for the conduct of the work. Each District Forester has supervision over the administration of the group of Forests, usually from 20 to 30, which are located within his District.

Altogether there are 162 Forests, averaging over 1,000,000 acres each. In charge of each Forest is a supervisor, who may or may not be a technical forester. In some cases he is assisted by a deputy supervisor. The Forests are divided into districts, each in charge of

a forest ranger, who is responsible for the protection of this area and for the conduct of the local business upon it. During the summer additional rangers and guards are employed to supplement the regular force. In addition to this executive force there are technical assistants to aid in scaling, in timber estimating, in surveying, in grazing, in land classification, and in other work which requires special technical knowledge and ability.

The following table shows the classification of the force on the National Forests on June 30, 1912, not including men in the District offices:

Supervisors	151
Deputy supervisors	100
Rangers	1,424
Guards	526
Forest examiners and forest assistants	129
Timber and mining experts, engineers, land examiners, hunters, etc	112
Clerks	182
Total	2,624

The first task on the National Forests has been that of protecting them and of organizing their business administration. Protection of the Forests from fire is of fundamental importance, and every effort has been directed toward this end. Not only have patrolmen been employed to be on the lookout for fires, but all the permanent improvement work, such as the building of roads, trails, and telephone lines, has been planned with the specific object in view of making them of the greatest use in fire protection. In addition to this protective work, the constantly increasing use of the Forests has necessitated the handling of an immense amount of current business. During the fiscal year ending June 30, 1911, for example, 830 million board feet of timber were sold, and 7,400,000 head of sheep and goats and 1,400,000 head of cattle and horses were grazed on the National Forests. At the same time the Forests resources are used through permits for power development, irrigation, summer residences, hotels, and a great variety of other special uses.

All of these different lines of work are handled by the regular administrative force, under the immediate direction of the supervisor. From the very beginning an effort has been made to apply the best forestry possible under the given conditions, and the more technical phases of the work have accordingly been handled as far as practicable by the men with a technical education, the forest assistants. They have had to perform such duties as mapping and estimating the timber on the Forest, marking the trees to be removed in timber sales, raising stock at nurseries for field planting, and

reforesting unproductive treeless areas either by planting or by direct seeding. The rangers also have been called upon to do work of this character, in addition to their regular work of protection and routine administration. Many of them have become very proficient in it, and will undoubtedly have more and more of it to do as the business of the National Forests increases. The next step in the development of the Forests is the preparation of detailed plans for the administration and use of their resources. These plans will place the management of the Forests on a far more definite and permanent basis, and both their preparation and execution will require technical ability of a high order.

INVESTIGATION AND COOPERATION.

The investigative work of the Forest Service is of two kinds: That designed primarily to aid in the development of forestry on the National Forests, and that designed to aid in the development of forestry throughout the country. To accomplish the first of these purposes six forest experiment stations, similar in scope to the agricultural experiment stations, have been established on the National Forests in the West. These experiment stations are in charge of specialists, who devote their entire time to scientific investigations, the result of which will lead to better methods of forest management. For example, detailed investigations are now being carried on to determine the best methods of artificial reforestation under given conditions, the best methods of cutting in different forest types to secure natural reproduction, the rate of growth of trees left after lumbering, and similar studies. In addition to these experiment stations, investigative work is being done on the various National Forests by the technically trained men assigned to them. In this way a vast amount of information is being accumulated in all parts of the West, which will be of the greatest value in putting the management of the Forests on the best possible foundation.

The investigative work outside of the National Forests is conducted from the Washington office. The total force permanently engaged upon this work varies from about 20 to 30 men, with additional assistants during the field season. The work is designed to make available for private owners much the same information regarding their forests as the Government desires concerning the National Forests. Special studies are made of individual problems of importance, and the results are made generally available through publications.

Closely connected with the investigative work is the cooperation offered to private owners and to States. In States without a State forester, advice in regard to the best methods of forest management and in regard to planting is furnished by the Service to small timber-

land owners who are willing to pay the expense of the necessary examination. Work is also done in cooperation with the States in general studies of their forest conditions, in outlining State forest policies, and in recommending legislation.

The investigative work in forest products is largely concentrated at Madison, Wisconsin, where the laboratory of forest products is located. There are branch offices in Washington and in several of the District offices, and cooperative work is carried on at Seattle in connection with the University of Washington, and at Boulder, Colo., in connection with the University of Colorado. The total number of technical men engaged in investigative work in forest products varies from about 40 to 50. Of these, however, only a comparatively small number are technical foresters, the rest being engineers, chemists, and specialists in other lines. Very detailed studies are made of such problems as the preservative treatment of timber, the physical and mechanical properties of wood, wood distillation, the use of different species for paper pulp, and the decay of wood.

A new line of work recently undertaken by the Forest Service is the examination of land in the White Mountains and Southern Appalachian Mountains for purchase under the provisions of the Weeks Law. A force of about 30 technical foresters is engaged on this work, and temporary men are employed from time to time as occasion arises. Under the provisions of the Weeks Law assistance is also given to various States in protecting from fire the forested watersheds of navigable streams. This work requires the employment of several hundred Federal patrolmen to perform duties similar in a large measure to those of the ranger or guard on the National Forests.

HOW THE FORCE IS RECRUITED.

All permanent positions in the Forest Service are in the classified civil service. The main force is recruited through two civil service examinations, that of forest assistant and that of forest ranger. The first is a highly technical examination, and requires a training equivalent to that given at the best forest schools. The ranger examination is of a very practical nature, requiring field training and experience, together with some knowledge of several phases of technical forestry. There are also a number of technical positions in other lines of work which are occupied by specialists recruited from special civil service examinations. Among these are mineral examiners, lumbermen, scalers, engineers in timber tests, chemical engineers, draftsmen, land examiners, land law clerks, and others.

The important positions in the Forest Service along executive and administrative lines are filled by the promotion of men who have shown special merit. Most of the forest supervisors and deputy

supervisors are men who have been promoted either from forest assistant or from forest ranger.

With the exception of the Forester and the Associate Forester the salaries of the higher officials in administrative and investigative work in the Washington and District offices vary from $2,000 to $3,750 per year. The salaries of supervisors range from $1,400 to $2,700; of deputy supervisors from $1,400 to $1,700; of forest examiners from $1,600 to $2,200; of forest assistants from $1,100 to $2,000; and of rangers from $900 to $1,500 per year.

The Forest Service force has increased within a comparatively short time from only a few men to a total of between three and four thousand. Until 1911 practically every person who passed the civil service examination for forest assistant was taken on the force. There is now, however, a complete administrative organization with a specified number of positions, and the future growth of the Service will necessarily be much slower. This has led to the general impression that unless there are very largely increased appropriations there will be no opportunity for new men in the Forest Service. In a sense this is true, because there will be but a small increase in the number of positions. At the same time it is likely that a certain number of new men will be needed every year. The Forest Service is a very large organization, and a new one, and a great many changes in personnel are occurring all the time. Doubtless it will ultimately be a very much larger organization than at present. It is inevitable that many of the Forests will be subdivided, as it becomes possible to make their administration more intensive, and that the investigative work will develop considerably.

For replacement in the ranks of forest assistants some twenty new men will probably be required each year. In addition there will be opportunity for a number of men to enter the Service as rangers, with the possibility of promotion later to more technical positions. Inasmuch as the high-grade forest schools are now turning out several hundred men each year, this means that the time has arrived when the Forest Service can no longer take care of all their graduates, and that a considerable number must look elsewhere for employment.

STATE WORK.

During the last few years there has been a constantly increasing activity in forestry among the various States. Whereas only a few years ago not over half a dozen States employed trained foresters, to-day more than 20 different States have some kind of organization for forest work. These include the New England States, New York, Pennsylvania, New Jersey, Maryland, North Carolina, Kentucky, Ohio, Indiana, Michigan, Wisconsin, Minnesota, Kansas, Colorado, Montana, Idaho, Washington, Oregon, and California.

The character of work which a State forester has to do depends upon the stage of development of forestry in that particular State. In one where forestry is just beginning to receive attention, his first efforts must be largely along educational lines. Ordinarily he receives a small appropriation, and his chief task is to develop a forest policy for the State and to educate the people to a better handling of the forests within its borders. He must study the needs of the State, and then go before the people and show them what must be done to put into effect the policy which he has formulated. He usually has to make a great many public addresses, issue bulletins, write articles for the magazines and newspapers, and in every other way possible bring his message to the people. He must secure legislation and appropriations, and ordinarily has but little opportunity for doing technical forest work.

On the other hand, in those States where there is already a settled forest policy, the State forester's work is of a very different character. In such States the problem of fire protection absorbs a large amount of his time, and there is usually much administrative work to be done. Many States already have State forests, or are planning to acquire them. Their management naturally falls to the State forester, and gives him an opportunity to do some real technical work. Some of the States also, as, for example New Hampshire, Vermont, Connecticut, New York, Pennsylvania, Ohio, and Michigan, maintain nurseries for the production of plant material for distribution to citizens. The work of these nurseries must be directed by the State forester. Usually also he assists private owners in the management of their woodlands. This is done both by correspondence and by actual examinations of specific tracts, with recommendations for their management. All these duties give the State forester a wide scope for work along both administrative and technical lines.

Ordinarily the State forester is a thoroughly trained technical man. In some States where the work is just beginning to develop he is alone in the office, but more often he has one or more assistants. Not infrequently he has charge of a force of rangers, who are employed chiefly in fire patrol. In many cases he cooperates in this work with organizations of private owners and with the Federal Government.

The salaries of State foresters vary from $2,000 to $4,000 a year, but most of them receive about $2,500 a year. Their assistants ordinarily receive from $1,000 to $2,000.

Work in State forestry has just begun. It is possible to look forward to the time when every State with any forest interests will have an organization whose duty is to make the most of its forest resources. When this time comes there will be an active demand for men in State work, not only in the more responsible position of State forester, but also as assistants. It is true that this field is not unlimited, but it is nevertheless an extremely important one, and it will probably be a long time before it will cease to absorb a certain number of new

men each year. For the immediate future the demand on the part of the States for trained men will probably be nearly as great as on the part of the Federal Government.

PRIVATE WORK.

The timberlands belonging to private individuals are more extensive and more valuable than those publicly owned. Of the total stand of merchantable timber in the country, fully four-fifths is in private ownership. It is apparent, therefore, that the forest problem is not by any means confined to the public lands. Private forestry really offers the broadest field to the trained forester, and it is there that the profession may be expected to make the greatest expansion in the future.

Private owners may be classified in a general way as lumber companies; public service corporations, such as railroad and water companies; mining companies; recreation and hunting clubs; large private estates; and farmers and other small wood-lot owners.

So far the principal activities in forestry on the part of the large lumber companies have been in protecting their holdings from fire. In northwestern Montana, northern Idaho, Washington, and Oregon large lumber companies have taken a very progressive attitude toward the question of fire protection. They have organized timber protective associations, and have employed trained men to put into effect systematic plans for fire protection. Similar action has been taken by some of the lumbermen in the Northeast, notably in Maine and New Hampshire. In other parts of the country the work of fire protection has been largely carried on by the individual lumberman, and has been for the most part spasmodic and unsystematic. Nevertheless, there is a constantly growing appreciation of the need for such work, and systematic fire protection on the part of the lumber companies in nearly all parts of the country may be looked for in the near future.

Although there is a steadily increasing interest in forestry among lumbermen, relatively few foresters have as yet been employed by them. The technical work that has so far been done by the lumber companies has been elementary in character and of such a nature that it could be conducted by practical men already in their employ. The large companies in the far West have taken the position that fire protection is the problem of first importance and that all questions in technical forestry, including reforestation, must come second. A number of large paper companies in the East, however, have gone a step farther, and, in addition to protecting their holdings from fire, place a minimum limit upon the size of the trees cut in their operations. Some of these companies are even beginning to reforest their waste lands.

A big opportunity exists in the lumber industry for practical foresters with business ability. The forester who enters the lumber business must be prepared to estimate standing timber, appraise stumpage, determine the best method of cutting, estimate the future growth, lay out logging roads and railroads, and participate in actual lumbering and milling operations. As soon as foresters show their fitness for practical work of this character, there is no doubt that there will be a keen demand for their services. Fitness for this work will require entering the lumbering business at the bottom, and learning its practical and business details in a long and exacting apprenticeship. This field, however, offers probably the greatest opportunity for trained foresters in the future, both as to the number of men who will be required and the ultimate rewards for success, in salary and responsibility.

There is also a broad field among public service corporations which own timberlands. Most railroads own a certain amount of forest land, and the holdings of some, as the Northern Pacific, the Southern Pacific, and the Santa Fe, are very extensive. A few of these companies have already adopted a consistent and permanent policy of holding their timberlands, and are introducing systematic forest protection. The next step will be the inauguration of a system of forest administration somewhat similar to that on the National Forests. Some of the eastern railroads are considering the acquisition of forest lands, with tree planting wherever necessary, for the production of their own wood supplies, and the Pennsylvania, for example, has already put this policy into effect. So far the number of foresters employed by railroads is small, but the field is there, and ultimately will call for trained men.

Many water companies hold extensive tracts of timberland on the drainage areas from which their water supplies are derived. These companies have, for the most part, adopted the definite policy of maintaining such land in forest growth. They will unquestionably in many cases find it to their advantage to employ professional foresters to keep the forest cover in the best possible condition while at the same time yielding a revenue.

Frequently mining companies own lands which are covered with tree growth. Many of the mining companies in the southern mountains, especially coal mining companies, own considerable areas of land which they wish to hold for mineral development and also for the production of wood and timber for use in the mines. Some of these companies have already interested themselves in the question of treating timbers with chemical preservatives, and others have taken up the problem of conservative management of the forest land which they own.

Another class of private owners consists of those who have acquired forest property for hunting and other recreation purposes. Some of

these owners are already beginning to practice forestry, and are employing foresters to take care of their property.

At present relatively few large tracts of land in private estates are administered under forestry principles with a technical forester in charge. More often the work on the ground is taken care of by a resident ranger or woods foreman, and where any technical work is done it is directed or supervised by a consulting forester who visits the tract only at intervals. Most of the forestry work so far done on private estates has been of this character, and except in the case of the largest owners will probably continue to be. Already there are a number of private firms and individuals with headquarters in New York, Boston, Philadelphia, and elsewhere, who do work as consulting foresters.

This phase of professional work will undoubtedly develop to a considerable degree, as the principles of forestry become better known and more generally recognized in the management of private woodlands. Work as "consulting foresters" will be the natural goal of many of the more mature and experienced men who have acquired a solid footing in the profession. It will also offer opportunities for the employment of younger men as assistants and members of field parties. Some of the larger firms of consulting foresters now established require a permanent staff of trained men to carry on their work. The number of such openings to foresters entering the profession will undoubtedly be materially increased in the future.

Artificial reforestation by private owners is now assuming considerable importance. Already approximately a million acres have been planted, and interest in the subject is steadily increasing. There is accordingly a profitable field for professional foresters in collecting seed and raising nursery stock, either as a business by itself, or in connection with other forestry work.

The development of private forestry in this country will depend in part upon favorable legislation with respect to taxation of growing timber and upon fire protection by the States, but in part also upon the individual work of the foresters themselves. If foresters prove practical and can demonstrate to an employer that their work is profitable, there is no question whatever that there will be plenty of employment. The field is there, and it is an enormous one. It remains only to be developed, and there is little question that the foresters who are being turned out in such large numbers from the various forest schools will solve the question, particularly when the development of such work is necessary for their own existence.

The compensation in private forestry depends entirely upon the earning capacity of the individual. Ordinarily foresters under salary will be paid for their technical work practically the same as public forest officers, and undoubtedly employers will take public

salaries as the standard. Where the forester works into a regular business, however, as for example into the lumber business, his remuneration will depend more upon his business capacity and what he can do for the company in a business way than upon his technical attainments. Without any question some consulting foresters will be able to carry on a very prosperous business, especially when they have established a national reputation which will cause a demand for their services in the solution of particularly important problems.

TEACHING AND RESEARCH WORK.

The vocation of teaching offers many advantages to the technical forester. While the field is a rather limited one, there are still many openings for men with practical field experience and ability as teachers. The comparatively large number of schools in this country now offering complete courses in forestry has demanded more men with experience than could readily be found, and it is not likely that this field will soon be overcrowded. The teacher of forestry has the advantage of being able to spend much of his time in the field and to carry on original studies in connection with the regular school work.

Closely associated with educational work is research work. So far this is an almost untouched field. There can be no question, however, that it is an extremely important one, which offers attractive opportunities to a limited number of suitably trained men. Carefully conducted scientific investigations must lay the foundation for all practical woods work, and the men who carry on these investigations are really guiding the development of forestry. These investigations must be not only along lines which have always been generally recognized as belonging to forestry, but also along such lines as forest entomology, pathology, meteorology, and soils. It can hardly be questioned that in investigations of this character a technical and practical training in forestry would be of especial value.

Research work will be carried on at educational institutions, by the Federal Government, to some extent by the individual States, and possibly at privately supported experiment stations. As in other scientific work the compensation will not usually be so large as for high-grade administrative work, but will undoubtedly be sufficient to afford a comfortable living.

Approved:

JAMES WILSON,
Secretary of Agriculture.

WASHINGTON, D. C., *July 1, 1912.*

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EXTRACTING AND CLEANING FOREST TREE SEED.

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EXTRACTING AND CLEANING FOREST TREE SEED.

The extraction and cleaning of seed from cone-bearing trees are essential steps in artificial forestation. Economical methods and devices for doing this work have not yet been fully developed or standardized in the United States. Even the fundamental conditions necessary to prevent overheating, crushing, molding, and other injuries to seed, in extracting and cleaning, are not thoroughly understood. This is particularly true where small quantities are handled with simple appliances. The following directions, compiled from the experience of a number of members of the Forest Service, are designed to meet the needs of Forest officers and others who extract and clean seed in small amounts, without the facilities of a fully equipped plant.

STORING CONES BEFORE DRYING.

It is always preferable, especially when only natural heat is to be used, to begin drying cones at the earliest possible opportunity. When artificial heat is to be used finally, preliminary drying keeps the cones in good condition and enables them to be opened more readily later. The best method of handling cones is to spread them on canvas drying sheets in the open as soon as they are received. In fair weather this should always be done. If the weather is unfavorable, cones should be spread on canvas sheets in a dry building where plenty of air is circulating. Where there is not enough space to do this, they should be dumped into bins separated from each other by slat partitions set about one-half inch apart. Ventilating pipes, through the center of each bin, will increase the air circulation.

A fair makeshift for these methods is to pile the cones in heaps in the open or in a well-ventilated room. If in the open, they should be covered during wet weather in order to keep them as dry as possible. In any event, the cones should be shoveled or raked frequently to provide ample ventilation and prevent molding or mildewing. They should not be left in tied sacks, but if this is not avoidable they should be stored only in a dry, cool room. They should never be stored in dark, damp, or ill-ventilated rooms. Such conditions almost invariably cause molding and mildewing, and may lead to premature germination. If mildewing starts, the cones should be spread on sheets in the sun and dried as thoroughly and rapidly as possible.

Every precaution should be taken to keep away squirrels, chipmunks, and other rodents. This can ordinarily be done by the use of poisoned grain.

HANDLING CONES IN TRANSIT.

In transporting cones to the place of extraction similar precautions should be taken to keep them dry and to prevent heating. Ordinarily the best method of shipping is in sound gunny or sugar sacks, closely tied to prevent loss of loose seed. When shipped in carload lots stock cars should be used if possible, since these afford the best circulation of air. If box cars must be used, the small doors or windows in the ends of the cars should be left open. The sacks should be stacked in rows with air spaces between them and between the outer rows and the sides of the car. Ample space for circulation of air should be left also between the tops of the stacks and the roof of the car.

Seed which has ripened naturally and which has been extracted without having been subjected to dampness or overheating is better than that extracted from mildewed or moldy cones. Any precautions taken to avoid these unfavorable conditions will produce seed of higher quality.

DRYING CONES BY NATURAL HEAT.

WHERE NATURAL DRYING IS PRACTICABLE.

With favorable weather conditions the seed of nearly all coniferous species, except lodgepole pine, can be extracted by the heat of the sun. Where this method can be used it gives the best and cheapest, though not always the quickest, results. In the southern Rocky Mountains it is nearly always practicable because of the clear skies, slight precipitation, and drying winds usually prevalent from October to December. In the central and northern Rockies sun drying is possible in normal seasons until about October 20. Thereafter it is uncertain and not to be depended upon as a method of extraction. Sun drying is impracticable on the west side of the Cascades in Oregon and Washington because of frequent rains. It can be used in the eastern parts of these States only under particularly favorable weather conditions. Sun drying can be used in southern California, but in the Sierras its success is doubtful, except in particularly dry seasons. In any locality this method may be precluded by an unusually wet fall, or it may be stopped in the midst of the season by unfavorable weather.

EQUIPMENT.

To extract seed to the best advantage by sun drying the work must be thoroughly organized in detail and the necessary equipment must

be on hand as soon as the first cones are received. The short period during which sun drying can be employed makes any delay in starting the work inadvisable.

The first requisite is a supply of 12 by 14 feet, 8-ounce canvas drying sheets. These are used both for spreading and covering the cones. If canvas sheets are not available wagon covers, tents, tent flies, burlap, and heavy muslin are substitutes. A sufficient number of drying sheets at the outset is essential, and their shortage has heretofore been one of the greatest drawbacks to successful work.

If trays or raised platforms are to be used in drying, in connection with sheets, these should also be ready when the cones are received. One or more shovels and wooden rakes should be available.

SELECTION OF SITE.

The site for open-air drying must be carefully selected. An open place on top of a low ridge or bench is usually preferable. Small openings surrounded by bodies of timber are not suitable, because the trees prevent good circulation of air. The ground should be level, or, preferably, sloping gently toward the south, and should be thoroughly cleared of brush, weeds, stones, and other rubbish before work begins. If no favorable site can be found in the neighborhood of the collecting area or if it is anticipated that drying can not be completed before wet and cold weather sets in it may be best to select a site at a lower altitude, where drying will be more rapid and can be continued until a later date. The facilities for transporting the cones must, of course, be considered.

SPREADING THE CONES.

Before spreading cones for drying it is advisable to run them over a coarse screen to separate loose sticks, twigs, stones, dirt, needles, and other débris. If this is not done such material becomes mixed with the seed and makes future cleaning more difficult.

After the cones have been cleaned they should be spread on the canvas sheets in a thin layer, ordinarily not more than one cone deep, so that all are exposed to the air. They should be raked over at least once a day in order that all parts of the cones may be exposed to both sun and wind. If lack of space makes it necessary to spread to a greater depth, the cones should be raked or shoveled at least four times a day. Cones should never be piled deep. Considerable seed is usually obtained from the cones by raking while drying, especially during the hottest part of the day, but further extraction is nearly always necessary.

Keeping cones off the ground.—In continued dry weather good results can be obtained by spreading the sheets directly upon the

sufficient room for expansion, however, it is safer, in planning on the number of drying sheets needed, to allow only 8 or 9 bushels to each sheet.

Time required.—The time required for cones to open varies greatly with climatic conditions and slightly with different species. A succession of clear, sunny days and frosty nights, with good winds, will open cones very rapidly. In good weather mature yellow pine cones will open in from 3 to 5 days. Under ordinary weather conditions from 4 to 10 days are required, and in damp, stormy weather often as many as 15 days. Douglas fir and Engelmann spruce usually require a day or two longer under the same conditions. Lodgepole pine takes so much longer that sun drying is seldom attempted. Cones picked early in the season, before they are thoroughly ripe, open much more slowly than those picked later.

Number of sheets needed.—An estimate of the number of drying sheets needed for 1,000 bushels of western yellow pine cones may be made as follows: Ten bushels of cones can be spread on each sheet; if it takes 5 days to open each batch of cones and there are 20 good drying days in the fall each sheet can be used four times. In other words, 40 bushels can be handled on each sheet. Dividing 1,000 by this gives 25, the total number of sheets needed for the work. Bad weather or the need of additional sheets for covers may make this number insufficient. It is always well, therefore, to make the estimate liberal, since lack of a few drying sheets at a critical time may cause serious delay and even the loss of much seed.

DRYING CONES BY ARTIFICIAL HEAT.

With lodgepole pine, and with other species when weather conditions are unfavorable, artificial drying must be used. This method is quicker than drying by natural heat and is not dependent upon the weather. It is, however, more difficult, more expensive, and ordinarily does not yield as good seed; therefore it should not be used except when outdoor drying is not practicable. Most of the artificial drying is done at permanent, fully equipped extracting plants to which cones are shipped from a large area. This circular is designed for the smaller, temporary plants which must be handled by less experienced men with simple appliances.

EQUIPMENT NEEDED.

Cabins.—The first essential in drying by artificial heat is some sort of shelter which will protect the cones from weather and be sufficiently tight to make it possible to raise the temperature to at least 110° F. An empty room in a cabin may serve the purpose and often makes as satisfactory a substitute for a regular kiln as can be obtained. It must have tight walls and plenty of space for trays around the sides and for a stove. Often one room of a cabin is used for drying and another for storing and extracting.

Tents.—Large tents with high walls make fair drying rooms; 12 by 16 foot or 16 by 20 foot tents with 5 or 6 foot walls may be used, but larger tents have given the most satisfactory results. Drying is more difficult in tents than in buildings, but the former have the great advantage of being readily transported from place to place where cones are collected. Ordinarily the largest tents are used for drying and smaller tents for storing and extracting.

Stoves.—Small, temporary drying rooms are almost invariably heated by stoves. In buildings, box stoves equipped with drums have been generally used with satisfactory results. In tents, low, conical stoves have been more frequently used, but, as a rule, with poorer results. They are cheap and easily put up, but require constant attention. Empty cones will not burn well in them. These are serious drawbacks, and the use of box stoves with drums is prefareble.

Drying trays.—The cones are usually spread in trays with wire bottoms arranged in racks along the sides of the room or tent. Trays are generally made of 2 by 4 inch material, and vary in size from 2 by 3 to 3 by 4 feet. The larger trays are used only with lighter cones, since they are more difficult to handle, especially where space is limited. The bottom of the tray is wire netting, usually with a $\frac{1}{2}$-inch mesh for lodgepole pine and with a $\frac{3}{4}$-inch mesh for species with larger cones. Twelve square feet of tray space hold approximately 1 bushel of cones, spread thinly.

Cones may also be spread on pieces of wire netting stretched horizontally between the racks at intervals of 6 or 8 inches, with a vertical strip at each end to prevent them from falling on the floor when raked. Handling the cones is more difficult with this method, and the apparatus is less easily transported from one place to another. With either method a strip of canvas should be spread on the floor to catch the seeds as they fall through the netting, unless the floor is so smooth that seed can readily be swept from it without the use of canvas. It is essential that the trays be far enough apart to permit ample circulation of air. There should be a liberal supply of high registering thermometers to keep an accurate record of the temperature in different parts of the drying room.

FIRE PRECAUTIONS.

With the high temperature and dry air prevailing in the kiln room, extreme precaution must be taken to prevent fire. Where water pressure is available, a hose should always be connected and ready for use. Chemical fire extinguishers should be secured as additional safeguards. If neither of these measures is practicable, several buckets should be kept filled with water, to be instantly available.

DISTRIBUTION OF HEAT.

One of the most difficult problems in running an improvised kiln is to maintain a constant supply of heat and distribute it evenly through all parts of the drying room. The first step should be to make the room, whether in a building or tent, as tight as possible, except for the vents required for ventilation. All chinks in a building should be closed completely. The next precaution is to secure as constant temperature as possible. Wherever practicable, as hot a fire should be kept up at night as during the day. This is particularly necessary in a tent, where any dying down of the fire at night causes the air to cool rapidly, with consequent delay and loss of time and labor.

The stove has ordinarily been placed in the center of the room and approximately level with the lowest tiers of trays. This results in much slower drying of the cones near the bottom of the room and at a distance from the stove. Attempts have been made to obviate this difficulty by dividing the stovepipe into sections and carrying it through as much of the room as possible, but without complete success. Better drying is secured in the farther ends of the room, but the bottom remains much cooler than the top. This difference is especially marked in tents, where cold air constantly passes in under the walls. With only one stove, even distribution of heat is impossible. With stoves set at opposite ends of the tent and connected by a single stovepipe, conditions are but little better. In one instance where this arrangement was used, a difference of from 20° to 30° F. was found in the temperature of the air at the highest and lowest trays in a six-tier stack

One method of hastening the opening of the cones in the lower trays is to raise them as the drying proceeds and the cones in the upper trays are removed. This, however, requires additional handling and loss of time. A better method wherever space is available is to place the lowest tier of trays somewhat above the stove. Room for air circulation is essential. The tiers of trays should be at least 6 inches apart vertically, preferably 8 inches, and the same distance from the walls.

Heating the dry room from below.—The best method of securing even distribution of heat, although not always practicable, is to have the drying room heated from below. If conditions permit, excavate under the building and place the stove below the floor. This will not only heat the room above more evenly, but furnishes additional space for spreading cones. The stovepipes should pass through as many parts of the dry room as possible. Still better results will be obtained if hot-air pipes can be conducted from the drum of the stove into the room above, and even more heat can be made available

by inclosing the stovepipes in jackets, which need not extend farther than the openings where the pipes pierce the floor.

IDEAL DRY HOUSE.

An ideal dry house contains three stories, built in the side of a hill to take advantage of gravity, and to utilize the earth which partly surrounds the building to prevent the escape of the heat. The cones are unloaded into the third story from a road on the hillside. From this storeroom, or preliminary drying room, the cones are dropped to the second floor or kiln room. The ground floor contains the extracting room, furnace, and other equipment. The furnace may consist merely of a large box stove, burning long sticks of wood, inclosed in a galvanized-iron jacket packed with mineral wool or asbestos to prevent radiation of heat. From this jacket the heat is conducted through two pipes into the drying room or kiln. The heat is thus used where it is most needed, and its escape into the space about the furnace prevented. The building can be built, if necessary, only two stories high, in which case the cones are either unloaded directly into the second story or kiln room, or stored on the ground floor until ready for drying.

VENTILATION.

The proper ventilation of drying rooms, while less difficult than the even distribution of heat, is fully as important. All undried cones contain some moisture. As this is driven off the air becomes more and more saturated. Saturated air not only prevents rapid drying of the cones, but may injure the seed embryos. German experiments indicate that damp cold air is much more harmful to seeds than dry warm air. Some method of ventilation—letting in fresh, dry air and letting out moist air—is, therefore, essential.

The method usually employed is to insert one or two ventilators in the roof of the building or tent and also in openings near the floor for the entrance of fresh air. The amount of air taken in and let out can be regulated by adjustment of the ventilators. Tents are usually so open at the bottom that it is not necessary to make special provision for fresh air. Where the drying room is heated from below, fresh air can be admitted through dampers or ventilators in the jacket surrounding the stove. Vents to maintain circulation should also be provided in the roof of the drying room.

While usually the best practicable, these methods of ventilation are necessarily crude and wasteful. As the air cools and absorbs moisture, it becomes heavier and sinks to the floor. Vents in the roof carry off much of the hot, dry, light air which should be retained. A certain amount of heavy moist air is, however, carried out with

the current, and the circulation of air, so essential to drying the cones, is maintained.

An improved method removes the saturated air directly from the floor by pipe ventilators extending from the floor through the roof. In one kiln, fresh air is admitted directly under a small box stove with a heating drum placed near the center of the room. As this air becomes heated it rises to the ceiling, where it spreads to the side walls and, cooling slightly, descends in a steady stream over the trays. Each tier of trays is set a little nearer the wall than the one above. The trays thus catch the descending current of hot air, which flows over them. They are slightly tilted toward the center of the room, so that as the air cools and absorbs moisture from the cones it runs off the lower edge of the trays like water from a roof. The saturated air is sucked up by pipe ventilators passing through the roof and having inlets at the floor level.

APPLICATION OF MOISTURE BEFORE DRYING.

Wetting cones before drying apparently does more harm than good with any species except lodgepole pine. Lodgepole pine cones dipped in very hot water for not over one minute have in some cases been found to open more readily and to give a higher yield than unmoistened cones. This treatment, however, should be applied only to very tight cones and should not be of sufficient duration to add appreciably to their water content. Its only advantage is in loosening the sealed tips of the cone scales. Experiments have also shown that live steam applied under a pressure of one-half pound for 30 seconds assists in opening cones without impairing the fertility of the seed. Such treatment, however, is possible only at fully equipped extracting plants.

Even with lodgepole pine, a preliminary wetting is not essential and good results are obtained without it. Continued soaking of cones has almost uniformly lessened the ease of extraction and yielded seed of poorer quality. As a general rule, the cones should be as dry as possible before they are put in the kiln. Preliminary drying in the open or in well-ventilated storerooms will hasten opening after artificial heat is applied.

TEMPERATURE REQUIRED.

The degree of heat and the length of time required to open cones vary somewhat with different species, but still more with the conditions under which the drying is done. In a well-equipped plant, drying may be finished in less than half the time required in a tent, even with the same temperature. It is, therefore, impossible to cite average figures of general application. Ordinarily, the higher the

temperature the quicker the drying can be accomplished. Dry heat, however, is more effective than moist heat, and heat that is too intense is very apt to impair the fertility of the seed. This is particularly true of intense moist heat. Often this injury to seed is not appreciated at the time, since the deterioration does not become apparent until several months later.

The maximum temperature which should ordinarily be applied to all species except lodgepole pine is 120° F. This can be raised safely to 130° F. if the air is dry and good ventilation provided. Lodgepole cones should not as a rule be subjected to a temperature of more than 140° F., although this can be raised safely to 150° F. under favorable conditions. Lodgepole pine cones are hardest to open; then come in order western white pine, western yellow pine, Engelmann spruce, and finally Douglas fir, which can often be dried satisfactorily at a temperature of 110° F.

TIME REQUIRED.

At well-equipped plants lodgepole pine cones should be thoroughly dried at a constant temperature of 140° F. in from 8 to 10 hours, and other species at a constant temperature of 120° F. in 10 to 15 hours, assuming that the cones are mature and moderately dry when put into the kiln and that the room is evenly heated and well ventilated. Under less favorable conditions these periods may be greatly increased. In one instance, lodgepole pine cones dried in a tent at 140° F. took 44 hours to open. The difference was due mainly to loss of heat in the tent and its uneven distribution. Preliminary drying of the cones for a few hours at 80° to 100° F. has been found an advantage. Opening will also be hastened if the cones are spread thinly in the trays and stirred frequently, to make the drying more uniform.

EXTRACTING SEED FROM DRIED CONES.

After the cones have been thoroughly dried, the next step is to extract the seed. Merely to rake over the cones as they are drying in the sun or kiln is the simplest but least efficient method. It is most successful with western yellow pine, but even with this species better results can usually be obtained by shaking. The practice of placing cones in sacks and beating them with clubs to loosen the seed has also proved unsatisfactory. It requires too much time and yields only a little additional seed, which is apt to be of poor quality.

TRAY SHAKERS.

In nearly every case, therefore, to secure the maximum amount of seed some method of shaking must be used to release the seeds from the opened cones. One of the earliest and simplest devices is a tray

or frame with a wire-screen bottom, in which the cones are shaken or worked over. The framework is usually of 6-inch boards, varying from 3 by 6 feet to 5 by 7 feet in size. One-half inch mesh woven wire is used for the bottom. The tray may be stationary, supported on legs; or equipped with handles at both ends, so that it can be shaken by two men; or equipped with handles at one end and suspended by ropes from a tree at the other, so that it can be shaken by one man. Either of the last two devices is more satisfactory than the first, since much more thorough shaking of the cones is possible. A canvas sheet should be spread beneath the shaker to catch the seeds as they fall through the screen bottom. A similar shaker, but of different size and shape, consists of a box 30 by 18 by 18 inches, without a top and with wire screen bottom. This, too, is hung from the limb of a tree and is shaken in the same way. It contains about a bushel of cones and has a capacity of 50 bushels a day. Wooden blocks are often put in tray shakers to increase the jarring effect.

BOX SHAKERS.

All of these devices, while crude, can be used to advantage when other methods are not practicable. Better results can be obtained by the use of revolving cone shakers. These may be either box-like or cylindrical in shape and are often known as "churns" or "drums." The box shaker has been more generally used. It may be constructed readily from a dry-goods box of proper size. It should be large enough to hold from 2 to 4 bushels of cones when half full. Four feet long by three feet square in cross section is a common size, although both larger and smaller boxes are used with good results. One or more sides of the box should be composed entirely of wire screen. A frame is needed for support, and the extracted seeds fall through to a canvas placed beneath. With most species a $\frac{1}{2}$-inch mesh is most satisfactory for the screen. With lodgepole pine a $\frac{1}{3}$-inch mesh lets the seed through as readily and keeps out more rubbish.

Half of one side of the box should be made into a hinged door through which the cones can be placed in or dumped out of the shaker. Lengthwise through the center of the box should be run an axis of 2 by 4 inch or 3 by 3 inch lumber, or 2-inch iron pipe, projecting through the box and supported at both ends like a windlass. By attaching a crank to this axle the whole box can be revolved. The efficiency of the shaker may be increased by placing small cleats inside the box or by adding small wooden blocks to the cones to increase the jarring effect. The additional devices are unnecessary and undesirable, however, with species such as western yellow pine, which give up their seeds readily, since it breaks up the cone scales and makes cleaning of the seed more difficult.

CYLINDRICAL SHAKERS.

A convenient size for the cylindrical shaker is 3 feet in diameter by 4 feet long. The ends are of wood, but the sides consist of heavy wire screening, usually with ½-inch mesh, supported by a wooden framework, and a hinged door. An axle is put through the center of the cylinder, a handle attached, and the entire machine set on a sawhorse or windlass.

Of these types of shakers, the box is more easily constructed, and is more effective with cones from which the seeds are extracted with difficulty, since the shaking is more violent. On the other hand, this is a disadvantage in the case of easily extracted seed, since it breaks up the cones and increases the amount of rubbish to be removed. Small cones, furthermore, like those of lodgepole pine, are apt to collect in the corners of box shakers.

Shakers of both types should be revolved at a rate which will just bring the cones to the top of the mass and then allow them to fall straight to the bottom. The speed necessary varies with different species, as does also the number of revolutions required to extract all of the seed. From 20 to 40 revolutions is ordinarily sufficient to get practically all of the good seed. Too much time should not be spent in trying to secure every seed, since those at the extremities of the cones, which are extracted with the most difficulty, are often imperfect, and their presence in good seed lowers the quality of the whole.

BARREL SHAKERS.

A barrel may be used for seed extracting in practically the same way as the devices already described. One and a half inch iron pipe, with a crank at one end, is run through the center of the barrel. With this as an axis the barrel is mounted on a box about 4 feet long, 2½ feet wide, and 3 feet high. Both ends of the barrel are screened, with one screen movable to permit filling and emptying. For convenience in handling the seeds a tray may be fitted into the box to catch them as they fall from the barrel. The large box is useful not only as a means of support but also to keep the seed from blowing away. A 40-gallon barrel, filled about two-thirds full, will hold from 2½ to 3 bushels of well-opened Douglas fir cones. Seed can ordinarily be extracted thoroughly by revolving the barrel about five minutes.

INCLINED SHAKERS.

Where seed extraction is to be conducted on a more extensive scale a shaker capable of handling a larger quantity of cones should be built. This is hardly worth while for less than 250 bushels of cones. A model which has been used successfully with yellow-pine cones consists of a wooden frame 3 feet square at the ends and 16 feet long,

over which wire screening is stretched to form a long oblong box. The frame is held rigid with four internal X-shaped cross braces about 5 feet apart, connected at the ends by horizontal slats or strips. The screening is stretched horizontally from end to end of the frame and should never be wound round the frame. The framework may, of course, be constructed to fit any width of screen. The ends of this long screened box or shaker are left open to allow the free passage of cones. Holes are bored through the center of the four cross braces before they are put in the frame, and when the whole box is assembled a 2-inch iron pipe, bent at the upper end so as to form a crank, is thrust through these holes and firmly fastened to the frame, the lower end projecting beyond the shaker for a short distance to form a support. This pipe is then set in two wooden frames so as to allow the shaker to revolve. The lower end of the churn should be mounted from 3 to 6 inches below the upper end, where the cones are inserted. A chute should be constructed at the upper end, so that cones dumped into the chute will roll directly into the shaker. When in operation the whole machine should be set on canvas sheets to catch the seed as it falls through the wire screens. One man is required to revolve the shaker, another to pour in the cones, and a third to remove the empty cones at the lower end. The total cost of this apparatus is about $5. It has a capacity of approximately 40 bushels of yellow-pine cones per hour. With other species which give up their seed less readily a modification of this design is necessary to secure a more violent shaking of the cones.[1]

SORTING CONES.

Various appliances to separate opened from unopened cones have been devised. These consist of slats so spaced as to permit the small, unopened cones to pass through while retaining the larger, opened cones, the principle being similar to that used in machines for grading fruit by size. Such devices generally give poor results on account of the irregular size of both opened and unopened cones. It is usually preferable to sort cones by hand. The small amount of seed, however, ordinarily obtained from cones which do not open in the first drying does not justify much expenditure for sorting.

SEED CLEANING.

IMPURITIES PRESENT.

After extraction from the cones, the seed contains impurities which must be removed. Aside from wings, these consist mainly of broken cone scales and needles, broken and empty seeds, resin, and dust.

[1] Illustrations of this machine and of a box shaker are given in Plate IV of Forest Service Bulletin 98, "Reforestation on the National Forests."

The amount of broken cone scales depends partly on the species and partly on the treatment to which the cones are subjected during extraction. Seed of species whose cones are very brittle naturally contains more extraneous matter of this character. With most species, however, it is possible to avoid breaking the cones badly if they are shaken out rather than crushed out. The common method of putting heavy blocks of wood in the shaker with the cones is excellent for species whose seed is hard to extract or whose cones are tough. For other species, however, this method is undesirable, since it not only increases the difficulty of cleaning the seed, but is apt to injure it. It is advisable, therefore, to use no more violence than necessary, even if this makes extraction slower. The loss of time will be more than offset by the greater ease of cleaning. Twigs and broken needles can be largely kept out by screening the cones before drying is begun.

The presence of broken seeds depends chiefly on the treatment of the cones, which has been discussed. Empty seeds are also present in nearly all samples. Their proportion depends partly on the species, but mainly on the season. In a poor seed year empty seeds are usually abundant; in a good seed year comparatively rare. They can be separated from good seed only by fanning.

The presence of resin in seed depends mainly upon the species. It is probable, however, that crushing or overheating the cones increases its amount. It is certain that overheating, by softening and melting the resin, makes it much harder to remove. When the cones are heated to such an extent that resin sticks to the seed, it is practically impossible to remove it. Dust is always present to a greater or less extent.

REMOVAL OF WINGS.

The seed of all western conifers commonly handled have wings, which are usually, though not necessarily, removed when the seed is cleaned. Removal of the wings probably decreases the germinative power of seeds to a small extent. It so greatly facilitates the ease with which they can be handled, however, that the practice is almost universal. In the pines, the entire wing may be detached from the seed with comparative ease, particularly if the seeds are first moistened slightly. With other species, however, the wings form part of the seed coat, and can be removed only by actually breaking them off. Moistening the seed is therefore of doubtful value.

By flails.—One of the oldest and commonest methods of removing wings is to work the seed over in seamless sacks, the mouths of which are securely tied. The sacks are beaten with light flails, usually of leather, or kneaded with the hands and knees. Sometimes the sacks are tramped under foot for a few moments, but this method impairs the quality of the seed. With the pines, to which this method is particularly applicable, the wings are more readily removed if the

seed is slightly moistened with cold water. This may be done readily by putting the seed in a box, adding a little cold water and stirring with a shovel.

Another application of the wet process is to pile the seed 6 or 8 inches deep on a cement or plank floor, sprinkle it lightly with water, and then beat it energetically with leather flails. The wings can often be removed completely with the use of very little water. A similar method of removing the wings from pine seeds is to moisten them slightly and then churn the mass in a cylindrical drum until the wings become detached.

Wet and dry process.—Whenever the wet process is used, the seed must be dried immediately so that its vitality will not be impaired. The relative merits of the dry and wet processes depend partly upon whether the seed is to be stored for some time or used within a few months. In the latter case the wet process is ordinarily safe. If the seeds are to be stored for a year or more the dry process should be used.

By churns.—Another method of removing wings is to rub the seeds together with a number of small wooden blocks. This may be done by churning the seeds and wooden blocks in a box or barrel mounted on an axle so as to be rotated, or by keeping the box stationary and applying friction by rotating brooms nailed to a spindle running through the center. In the latter case, if the box is tilted at a slight angle and a hole cut in the lower end, the seeds will gradually work out with the wings broken off.

By screens.—Still other methods depend wholly on the use of screens. The simplest of these is to rub the seed as it comes from the extractor over a fine screen fastened on an empty box or stout frame. The rubbing may be done with a stiff scrubbing brush, a block of wood covered with corrugated rubber, or a piece of tough carpet, or the hands covered with rough gloves. As the wings are rubbed off the seeds gradually drop through the screen, leaving a large part of the wings and all of the coarser impurities on top. One-sixth inch mesh is the best size for screening yellow pine and Douglas fir seed; with lodgepole pine and Engelmann spruce one-eighth inch mesh is preferable. The wings of the seed are more easily removed if the seeds are moistened slightly with cold water before screening.

With most species the first screening ordinarily does not remove the wings completely. To secure this final removal the seeds and small chaff coming through the first screen may be churned in a small cylindrical drum, covered with very fine-meshed wire, together with several small pieces of wood. This process removes the remainder of the wings, which, with other small particles of dirt, fall through the screening, leaving clean seed behind.

By mechanical cleaners.—A somewhat similar method, preferable when the work is done on a large scale, makes use of a mechanical cleaner or wing crusher. This consists of a rotating cylinder bearing upon the outside several scrubbing brushes with stiff bristles, which during about one-third of each revolution press firmly against a wire screen of fine mesh. The screen against which the brushes press as they revolve may be adjusted to regulate the pressure of the bristles against it. The seed is dropped into the space between the screen and the brushes, and the wings are removed as the seeds pass under the brushes; the fragments of wings and chaff drop through the wire screen. When using such an apparatus with pine seed a slight moistening of the seeds with cold water is advisable before putting them into the hopper.

FINAL CLEANING OF SEED.

The final cleaning of seed is done by screening and fanning. Thoroughly clean seed can not be obtained without fanning. Where no fanning mill is available, fairly clean seed can be obtained by passing the seeds through wire screens of different sized mesh to remove first the coarser particles, such as pieces of cone scales, twigs, and needles, and then the finer chaff and pieces of broken wings; and finally by winnowing the remaining seed in the wind or by bellows or other mechanical devices. A blacksmith's rotary blower has been used effectively in winnowing lodgepole pine seed.

Seed may be fanned in one of the ordinary farm machines for cleaning grain. It removes practically all broken and empty seed as well as much of the resin and other impurities if the draft is properly regulated and screens with the right-sized mesh are used. It is essential that the wings be removed from seed before fanning, otherwise many good winged seeds will be lost. Not infrequently, particularly with poorly adjusted machines, the seed must be fanned more than once before it is thoroughly cleaned.

Before purchasing grain-cleaning machines their adaptation to cleaning coniferous seed must be fully determined. Many of the ordinary machines have yielded but poorly cleaned seed with low fertility, even after running the seed through the mill six or seven times. This increases cost of power and labor and adds the expense of storing and handling a considerable amount of refuse with the seed. Two machines have proved satisfactory. One of the important points in selecting a fanning machine is to secure screens properly perforated for the species which is to be handled.

Certain impurities, such as pieces of cone scales, resin particles, and twigs of the same size and weight as seeds, can not be removed ordinarily by screening or fanning. The only way to get rid of these is to pick them out by hand, and this is seldom warranted. Such

foreign matter usually composes a very small proportion of the total weight of seed, and its presence does little if any harm.

SEED STORING.

Wherever possible, clean seed should be stored in air-tight receptacles of glass or metal. Seed stored in such receptacles retains its vitality under any conditions of temperature and moisture much better than in any other except cold storage, which is seldom available. Where neither of these methods of storage is available, the seed should be thoroughly dried and stored in a dry and cool place. Some deterioration will take place under these conditions, but ordinarily not sufficient within one year to be of serious consequence. The storing of seed in cement cellars with the wings attached has been found by Austrian experimenters to give better results than storage with the wings removed. It is doubtful, however, whether the slight saving in vitality offsets the advantage of handling and using clean seed. In every case the seed should be thoroughly protected from rodents, either by the use of poison, by being stored in rodent-proof buildings, or by being hung in sacks out of reach.

SUMMARY.

STORING CONES.

Make all arrangements to begin drying the cones as soon as they are received. This is necessary on account of the short season when outdoor drying is possible.

If storage is necessary, take every precaution to prevent the cones from heating or molding. Never store them in damp or ill-ventilated rooms.

DRYING BY NATURAL HEAT.

Use outdoor drying whenever practicable with all species except lodgepole pine.

Screen the cones before drying to remove needles and other foreign matter.

Do not spread the cones too thickly on the drying sheets.

Protect the cones while drying from rodents and from moisture.

DRYING BY ARTIFICIAL HEAT.

Make every effort to secure even distribution of heat and good ventilation.

Avoid sudden or extreme fluctuations in temperature.

Never let the temperature rise above 150° F. with lodgepole pine or above 130° F. with other species.

Do not wet cones before drying, except lodgepole pine, and then only superficially.

Do not pile the cones too thickly in the trays.

Have the best available apparatus for putting out fires always ready for use.

EXTRACTING SEED.

Do not break the cone scales in raking or shaking more than is absolutely necessary.

Extract the seed as thoroughly as possible, but do not attempt to secure every single seed.

CLEANING SEED.

If moisture is used in removing wings, dry the seed as thoroughly and quickly as possible.

Do not use moisture in cleaning any but pine seed.

Do not consider seed clean until wings, impurities, and empty and broken seeds have been removed.

STORING SEED.

Store clean seed whenever possible in air-tight receptacles.

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HENRY S. GRAVES, Forester.

FOREST PRODUCTS LABORATORY SERIES.

SERVICE TESTS OF TIES.

PROGRESS REPORT

BY

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Assistant Director, Forest Products Laboratory,

AND

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In Charge of Cooperative Projects.

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SERVICE TESTS OF TIES: PROGRESS REPORT.

THE NEED FOR SERVICE TESTS.

At the present time all railway maintenance engineers admit the advisability of protecting wooden crossties from decay and mechanical abrasion. The increasing number of ties which are given treatment and the many forms of mechanical devices to protect them against wear indicate this attitude. Nevertheless, opinions on the efficiency of the various treatments and devices differ widely because there is very little reliable information to show what method of preserving ties from decay is best or what kind of rail fastening yields most satisfactory results. To secure this knowledge some railroads have made efforts to keep records of the life of their ties by the use of dating nails or other means. Experience has shown, however, that it is practically impossible to secure satisfactory records by attempting to include all the ties placed. Much more accurate and valuable information can be secured, at lower cost, by obtaining complete records on a comparatively few representative ties than by incomplete or doubtful records covering all ties in service. For this reason special tests are now considered more valuable, and the former practice of driving dating nails into all treated ties is falling into disuse.

The demand for definite information on the durability of ties under conditions of service can not be met by laboratory experiments, because the conditions of practice can not be duplicated in the laboratory, nor can they be even remotely approached. Therefore the Forest Service undertook, in cooperation with various railroads and tie-treating plants, to obtain durability records of ties in actual service by means of carefully planned tests. The first test was started in 1902; at the present time there are in various parts of the country eight test tracks which have been established through this cooperation.

PURPOSE OF THE PUBLICATION.

This report is a record of the test tracks which have been laid and makes available the results which have thus far been secured. Owing to the complexity of the problem, and to the fact that in

most cases deterioration takes place slowly, many years must elapse before final conclusions can be drawn.[1]

GENERAL PROCEDURE IN THE TESTS.

In these investigations it is the general practice for the railroad companies to bear the entire expense of furnishing and treating the ties and placing them in the roadbed. The Forest Service plans the investigation, supervises the treating and the placing of the ties, makes frequent inspections, and compiles the data. With the exception of the ties placed in the track of the Chicago, Milwaukee & St. Paul Railway Co., all of the treated ties were treated in commercial plants. The test ties in the Chicago, Milwaukee & St. Paul track were treated in the experimental cylinder of the Forest Products Laboratory and in their case more complete records of their treatment are available than in any other.

In the inspections the following scheme is used for describing and classifying the ties:

Decayed.—Ties so decayed as to warrant their early removal from the track.

Partially decayed.—Ties partially affected with decay but still serviceable.

Split.—Ties noticeably split or checked but still serviceable.

Worn.—Ties noticeably damaged by rail or plate cutting but still serviceable.

Spike cut.—Ties in which the spikes are noticeably loose or have damaged the wood.

Good.—Ties not noticeably affected with decay and not badly split, checked, worn, or spiked.

In certain instances it has been agreed that no ties removed from a test track for any cause whatever will be destroyed until a representative of the Forest Service has inspected them. There was no such agreement, however, with the Gulf, Colorado & Santa Fe Railway Co., and the records of the Forest Service applying to this road are now so incomplete that no further examination of this track will be made by the Forest Service.

Throughout this publication patented and proprietary preservatives and processes are designated by the names by which they are generally known.

[1] For a record of test tracks laid by various railroads in the United States independent of the Forest Service, see Bulletin 144 (vol. 13) of the American Railway Engineering Association.

RECORDS OF TESTS.

TEST TRACK LAID IN COOPERATION WITH THE GULF, COLORADO & SANTA FE RAILWAY CO.

DESCRIPTION OF TRACK.[1]

The 5,477 ties which were placed in the test track laid in cooperation with the Gulf, Colorado & Santa Fe Railway Co. were laid in February, 1902, in a level tangent between Pelican and Cleveland, Tex. No tie-plates were used and the rails were spiked to the ties with ordinary cut spikes. The ballast was composed largely of densely packed sand, banked in the middle; the ends of the ties were exposed. Sixty and sixty-one pound rails were used. The drainage is poor; the traffic, which is mostly westward, averaged about 166,000 tons per month at the time the test ties were placed.

OBJECTS OF THE TEST.

This test was designed to obtain information as to:

(1) The durability of ties made from untreated beach; hemlock; black, red, Spanish, turkey, white, and willow oak; loblolly, longleaf, and shortleaf pine; and tamarack.

(2) The efficiency of the Allardyce, Burnett, Hasselmann, and Wellhouse processes, and of preservative treatments with Beaumont oil, with spirittine, and with zinc chloride in combination with Beaumont oil and with English creosote.

TREATMENT.

The ties treated for this track were obtained from various sources and it was impossible at the time to use great care in selecting them. Many of the ties, therefore, were possibly not of the best of their kind. The descriptions of the treatments of the various lots of ties, given in connection with Tables 1 to 11, which show their condition, are based on the reports made by the persons in charge of the treatments. The number of ties of each species treated by any one plant by a given process was relatively small and various species were treated in the same charge. The absorption records for the charges are therefore of doubtful value as to any one species.

[1] A report of the laying of this track and of the first and second inspections is given in Bulletin 51, "Condition of Treated Timbers Laid in Texas in 1902," by Hermann von Schrenk.

TABLE 1.—*Condition of ties treated by the Allardyce process,*[1] *at Somerville, Tex., after seven and one-half years' service.*

Kind of wood.	Original number placed.	Ties remaining in track.					Serviceable ties remaining in track.			
		Decayed.	Partially decayed.	Good.	Split.	Total.	Partially decayed.	Good.	Split.	Total.
		No.	*No.*	*No.*	*No.*	*No.*	*Per ct.*[2]	*Per ct.*[2]	*Per ct.*[2]	*Per ct.*[2]
Beech	50	7	7	27	9	50	14	54	18	86
Hemlock	50	19	10	11	10	50	20	22	20	62
Oak, black	60	3	3	36	18	60	5	60	30	95
Oak, red	10	.....	.....	10	.....	10	.....	100	.....	100
Oak, Spanish	10	1	2	7	.....	10	20	70	.....	90
Oak, turkey	10	.....	.....	10	.....	10	.....	100	.....	100
Oak, white	100	2	7	69	20	98	7	69	20	96
Oak, willow	10	1	4	5	.....	10	40	50	.....	90
Pine, loblolly	50	16	6	10	17	49	12	20	34	66
Pine, longleaf[3]	50	.....	.....	31	12	43	.....	62	24	86
Pine, shortleaf[3]	50	.....	.....	28	.....	28	.....	56	.....	56
Tamarack	50	7	5	32	5	49	10	64	10	84
Total	500	56	44	276	91	467	9	55	18	81

[1] These ties were treated at the plant of the Texas Tie & Lumber Preserving Co. Various species were treated in the same charge and the ties were given an average injection of 12 pounds of 2 per cent zinc chloride solution per cubic foot, followed immediately by an average injection of 3 pounds of creosote per cubic foot.

[2] Based on number of ties originally placed.

[3] Because of a change made in the location of some of the longleaf and shortleaf pine ties and of the loss of some of the marking rails, there is some doubt as to the accuracy of the records.

TABLE 2.—*Condition of ties treated with Beaumont oil,*[1] *at Somerville, Tex., after seven and one-half years' service.*

Kind of wood.	Original number placed.	Ties remaining in track.					Serviceable ties remaining in track.			
		Decayed.	Partially decayed.	Good.	Split.	Total.	Partially decayed.	Good.	Split.	Total.
		No.	*No.*	*No.*	*No.*	*No.*	*Per ct.*[2]	*Per ct.*[2]	*Per ct.*[2]	*Per ct.*[2]
Pine, loblolly	42	2	.....	.....	.....	2	.....	.....	.....	.....
Pine, longleaf	100	23	4	3	.....	30	4	3	.....	7
Total	142	25	4	3	.....	32	3	2	.....	5

[1] The treatment consisted of soaking the ties in the oil for 24 hours. The longleaf pine absorbed on an average 5.67 pounds, and the loblolly pine 4.24 pounds, per tie; the latter were not thoroughly seasoned before treatment.

[2] Based on number of ties originally placed.

TABLE 3.—*Condition of ties treated by the Burnett process,*[1] *at Chicago, Ill., after seven and one-half years' service.*

Kind of wood.	Absorption dry salt.[2]	Original number placed.	Ties remaining in track.					Serviceable ties remaining in track.			
			Decayed.	Partially decayed.	Good.	Split.	Total.	Partially decayed.	Good.	Split.	Total.
	Lb. per cu. ft.		*No.*	*No.*	*No.*	*No.*	*No.*	*Per ct.*[3]	*Per ct.*[3]	*Per ct.*[3]	*Per ct.*[3]
Beech	0.41	99	8	33	39	19	99	33	40	19	92
Hemlock[4]	.62	100	.....	7	35	27	69	7	35	27	69
Oak, red	.....	86	14	15	33	21	83	17	38	24	79
Oak, white	.26	101	.....	4	76	21	101	4	75	20	100
Tamarack	.41	49	1	3	32	13	49	6	65	26	98
Total	.....	435	23	62	215	101	401	14	50	23	87

[1] These ties were treated by the Chicago Tie & Timber Preserving Co. The treatment consisted of impregnation with a 4 per cent solution of zinc chloride.
[2] Based on weights of sample ties of each lot before and after treatment.
[3] Based on number of ties originally placed.
[4] Because of a change made in the location of some of the hemlock ties and of the loss of some of the marking nails there is some doubt as to the accuracy of the records.

TABLE 4.—*Condition of ties treated by the Burnett process,*[1] *at Somerville, Tex., after seven and one-half years' service.*

Kind of wood.	Original number placed.	Ties remaining in track.					Serviceable ties remaining in track.			
		Decayed.	Partially decayed.	Good.	Split.	Total.	Partially decayed.	Good.	Split.	Total.
	No.	*No.*	*No.*	*No.*	*No.*	*No.*	*Per ct.*[2]	*Per ct.*[2]	*Per ct.*[2]	*Per ct.*[2]
Oak, black	34	2	7	14	6	29	20	41	17	78
Oak, red	20	.....	.....	.....	.....	.....	.....	.....	.....	.....
Oak, Spanish	21	.....	.....	15	1	16	.....	71	5	76
Oak, turkey	20	.....	.....	.....	.....	.....	.....	.....	.....	.....
Oak, white	100	.....	.....	.....	.....	.....	.....	.....	.....	.....
Oak, willow	20	.....	.....	.....	.....	.....	.....	.....	.....	.....
Pine, loblolly	100	22	10	37	30	99	10	37	30	77
Pine, longleaf[3]	100	1	2	57	14	74	2	57	14	73
Pine, shortleaf[3]	100	.....	2	37	.....	39	2	37	.....	39
Total	515	25	21	160	51	257	4	31	10	45

[1] These ties were treated at the plant of the Texas Tie & Lumber Preserving Co. with a 2 per cent solution of zinc chloride. Various species were treated in the same charge; the average absorption for all species was 0.35 pound of dry salt per cubic foot.
[2] Based on number of ties originally placed.
[3] On account of a change made in the location of some of the longleaf and shortleaf pine ties and of the loss of some of the marking nails there is some doubt as to the accuracy of the records.

TABLE 5.—*Condition of ties treated by the Hasselmann process,*[1] *at Somerville, Tex., after seven and one-half years' service.*

Kind of wood.	Original number placed.	Ties remaining in track.					Serviceable ties remaining in track.			
		Decayed.	Partially decayed.	Good.	Split.	Total.	Partially decayed.	Good.	Split.	Total.
		No.	*No.*	*No.*	*No.*	*No.*	*Per ct.*[2]	*Per ct.*[2]	*Per ct.*[2]	*Per ct.*[2]
Beech	98	.....	.....	.....	.....	.....	.....	.....	.....	.....
Hemlock	100	.....	.....	.....	.....	.....	.....	.....	.....	.....
Oak, black	118	.....	.....	.....	.....	.....	.....	.....	.....	.....
Oak, red	19	.....	.....	.....	.....	.....	.....	.....	.....	.....
Oak, Spanish	20	.....	.....	.....	.....	.....	.....	.....	.....	.....
Oak, turkey	19	.....	.....	.....	.....	.....	.....	.....	.....	.....
Oak, white	196	1	7	22	2	32	3	11	1	15
Oak, willow	20	.....	.....	.....	.....	.....	.....	.....	.....	.....
Pine, loblolly	99	.....	.....	.....	.....	.....	.....	.....	.....	.....
Pine, longleaf	100	.....	.....	5	.....	5	.....	5	.....	5
Pine, redheart	100	.....	.....	.....	.....	.....	.....	.....	.....	.....
Pine, shortleaf	98	.....	.....	1	.....	1	.....	1	.....	1
Tamarack	98	9	.....	.....	.....	9	.....	.....	.....	.....
Total	1,085	10	7	28	2	47	½	2½	½	3½

[1] These ties were treated at the plant of the Texas Tie & Lumber Preserving Co. under the supervision of a representative of the Barschall Impregnating Co. The process, called also the Barschall process (Forest Service Bulletin 51), consisted of impregnations with a solution of copper sulphate, iron sulphate, alumina, and a small amount of kainit. The Barschall Impregnating Co. stated that certain of the ties showed decay before they were treated and that some of them were probably not properly treated because of a leak in the cylinder. Also, the records of treatment furnished by a representative of the company show that temperatures as high as from 224° to 270° were used during the treatments.

[2] Based on number of ties originally placed.

TABLE 6.—*Condition of ties treated with spirittine,*[1] *at Somerville, Tex., after seven and one-half years' service.*

Kind of wood.	Original number placed.	Ties remaining in track.					Serviceable ties remaining in track.			
		Decayed.	Partially decayed.	Good.	Split.	Total.	Partially decayed.	Good.	Split.	Total.
		No.	*No.*	*No.*	*No.*	*No.*	*Per ct.*[2]	*Per ct.*[2]	*Per ct.*[2]	*Per ct.*[2]
Pine, loblolly	100	2	.....	.....	.....	2	.....	.....	.....	.....
Pine, longleaf	100	.....	.....	17	3	20	.....	17	3	20
Total	200	2	.....	17	3	22	.....	8½	1½	10

[1] The ties were thoroughly seasoned and were soaked in the preservative 24 hours. The absorption averaged 3.3 pounds per cubic foot.

[2] Based on number of ties originally placed.

TABLE 7.—*Condition of untreated ties after seven and one-half years' service.*

Kind of wood.	Original number placed.	Ties remaining in track.					Serviceable ties remaining in track.			
		Decayed.	Partially decayed.	Good.	Split.	Total.	Partially decayed.	Good.	Split.	Total.
		No.	*No.*	*No.*	*No.*	*No.*	*Per ct.*[1]	*Per ct.*[1]	*Per ct.*[1]	*Per ct.*[1]
Beech	87									
Hemlock	101									
Oak, black	25									
Oak, red	93	6				6				
Oak, Spanish	20									
Oak, turkey	20									
Oak, white	196	5	27	13	4	49	14	6½	2	22
Oak, willow	21									
Pine, loblolly	100									
Pine, longleaf	93	6				6				
Pine, shortleaf	100	1				1				
Tamarack	49									
Total	905	18	27	13	4	62	3	1½	½	5

[1] Based on number of ties originally placed.

TABLE 8.—*Condition of ties treated by the Wellhouse process,*[1] *at Chicago, Ill., after seven and one-half years' service.*

Kind of wood.	Absorption[2] dry salt.	Original number placed.	Ties remaining in track.					Serviceable ties remaining in track.			
			Decayed.	Partially decayed.	Good.	Split.	Total.	Partially decayed.	Good.	Split.	Total.
	Lb. per cu. ft.		*No.*	*No.*	*No.*	*No.*	*No.*	*Per ct.*[3]	*Per ct.*[3]	*Per ct.*[3]	*Per ct.*[3]
Beech	0.87	100		9	51	40	100	9	51	40	100
Hemlock	.54	100	9	12	66	9	96	12	66	9	87
Oak, black	.53	86	3	9	43	17	72	10	50	20	80
Oak, white	.35	100	1	7	60	28	96	7	60	28	95
Tamarack	.58	100	3	11	72	14	100	11	72	14	97
Total		486	16	48	292	108	464	10	60	22	92

[1] These ties treated by the Chicago Tie & Timber Preserving Co. The treatment consisted of three injections: (1) A 4 per cent solution of zinc chloride; (2) a 2 per cent solution of glue; (3) a 2 per cent solution of tannin.

[2] Based on weights of sample ties of each lot before and after treatment.

[3] Based on number of ties originally placed.

TABLE 9.—*Condition of ties treated by the Wellhouse process,*[1] *at Somerville, Tex., after seven and one-half years' service.*

Kind of wood.	Original number placed.	Ties remaining in track.					Serviceable ties remaining in track.			
		Decayed.	Partially decayed.	Good.	Split.	Total.	Partially decayed.	Good.	Split.	Total.
		No.	*No.*	*No.*	*No.*	*No.*	*Per ct.*[2]	*Per ct.*[2]	*Per ct.*[2]	*Per ct.*[2]
Oak, black	33	2	7	6	.....	15	21	18	.....	39
Oak, red	20	.....	.....	.....	.....	.....	.....	.....	.....	.....
Oak, Spanish	20	2	3	15	.....	20	15	75	.....	90
Oak, turkey	20	.....	.....	2	.....	2	.....	10	.....	10
Oak, white	100	.....	7	41	10	58	7	41	10	58
Oak, willow	20	1	.....	9	2	12	.....	45	10	55
Pine, loblolly	100	23	16	49	11	99	16	49	11	76
Pine, longleaf[3]	100	1	5	35	4	45	5	35	4	44
Pine, shortleaf	100	.....	2	19	.....	21	2	19	.....	21
Total	513	29	40	176	27	272	8	34	5	47

[1] These ties were treated at the plant of the Texas Tie & Lumber Preserving Co. The treatment consisted of two injections: (1) A 2 per cent solution of zinc chloride containing glue; (2) a solution of tannin. The average absorption for all species was 0.33 pound of dry zinc chloride per cubic foot, various species being mixed in the same charge.

[2] Based on number of ties originally placed.

[3] On account of a change made in the location of some of the longleaf-pine ties and of the loss of some of the marking nails there is some doubt as to the accuracy of the records.

TABLE 10.—*Condition of ties treated with zinc chloride and Beaumont oil,*[1] *at Somerville, Tex., after seven and one-half years' service.*

Kind of wood.	Original number placed.	Ties remaining in track.					Serviceable ties remaining in track.			
		Decayed.	Partially decayed.	Good.	Split.	Total.	Partially decayed.	Good.	Split.	Total.
		No.	*No.*	*No.*	*No.*	*No.*	*Per ct.*[2]	*Per ct.*[2]	*Per ct.*[2]	*Per ct.*[2]
Pine, loblolly	81	4	7	39	31	81	8	48	38	95
Pine, longleaf	100	2	8	68	22	100	8	68	22	98
Total	181	6	15	107	53	181	8	59	30	97

[1] The ties were treated with a 2 per cent solution of zinc chloride and seasoned before treatment with oil. They were soaked in the oil 24 hours and absorbed on an average a little over 3 pounds per tie.

[2] Based on number of ties originally placed.

TABLE 11.—*Condition of ties treated with zinc chloride and English creosote,[1] at Beaumont, Tex., after seven and one-half years' service.*

Kind of wood.	Original number placed.	Ties remaining in track.					Serviceable ties remaining in track.			
		Decayed.	Partially decayed.	Good.	Split.	Total.	Partially decayed.	Good.	Split.	Total.
	No.	*No.*	*No.*	*No.*	*No.*	*No.*	*Per ct.*[2]	*Per ct.*[2]	*Per ct.*[2]	*Per ct.*[2]
Beech	50	.....	.....	.....	.....	.....	.....	.....	.....	.....
Gum, sweet[3]	10	.....	.....	2	.....	2	.....	20	.....	20
Hemlock	49	.....	.....	7	.....	7	.....	14	.....	14
Oak, black	76	.....	.....	.....	.....	.....	.....	.....	.....	.....
Oak, turkey	10	.....	.....	.....	.....	.....	.....	.....	.....	.....
Oak, white	107	.....	.....	.....	.....	.....	.....	.....	.....	.....
Oak, willow	11	.....	.....	.....	.....	.....	.....	.....	.....	.....
Pine, loblolly	51	.....	7	25	17	49	14	50	33	97
Pine, longleaf[4]	50	1	.....	26	4	31	.....	54	8	62
Pine, shortleaf[4]	50	.....	.....	8	.....	8	.....	16	.....	16
Tamarack	51	.....	.....	5	.....	5	.....	10	.....	10
Total	515	1	7	73	21	102	1½	14	4	19

[1] These ties were treated by the International Creosoting & Construction Co. They were first impregnated with an average of 15 pounds of a 2 per cent zinc chloride solution and, after seasoning for several months, were given a heavy injection of creosote. From the report of the operations it seems very probable that they were injured by excessive steaming and many of them were said to be of poor quality before treatment. It is reported that all of the removals were due to breakage and rail cutting.

[2] Based on number of ties originally placed.

[3] Forest Service Bulletin 51 reports these ties as Spanish oak.

[4] Because of a change made in the location of some of these ties and of the loss of some of the marking nails there is some doubt as to the accuracy of the records.

RESULTS.

The results secured from the last inspection made by the Forest Service in September, 1909, are given in Tables 1 to 11. Figures 1 and 2, which show graphically the results of the test, are based on this and other inspections.[1] The following deductions may be drawn:

(1) Zinc chloride is an effective preservative for ties subjected to the severe conditions under which these were laid. This is indicated especially by the Burnett and Wellhouse treatments made at Chicago (Tables 3 and 8), as a result of which 87 and 92 per cent, respectively, of these ties were serviceable after seven and one half years.

(2) A fairly heavy impregnation of zinc chloride is advantageous. Treatments by the Burnett and Wellhouse processes, made at Somerville, with 2 per cent zinc chloride solutions and average absorptions of 0.35 and 0.33 pounds of dry salt per cubic foot of wood, resulted in only 45 and 47 per cent, respectively, of serviceable ties after seven and one-half years' service (Tables 4 and 9). Similar treatments made at Chicago with a 4 per cent solution and average absorptions of 0.42 and 0.57 pound of dry salt per cubic foot resulted in 87 and 92 per

[1] The results of inspections made in 1905, 1906, 1907, 1908, and 1910 were courteously supplied by the officials of the Atchison, Topeka & Santa Fe Railway Co.; the Forest Service made inspections in 1903, 1904, and 1909 only.

cent, respectively, of serviceable ties after the same length of service (Tables 3 and 8).

(3) A light injection of creosote apparently adds to the effectiveness of zinc chloride treatments. The Allardyce treatments made at Somerville (Table 1) show 81 per cent of serviceable ties, while treatments made at the same plant with zinc chloride alone (Table 4) show only 45 per cent of serviceable ties after 7½ years. Beaumont

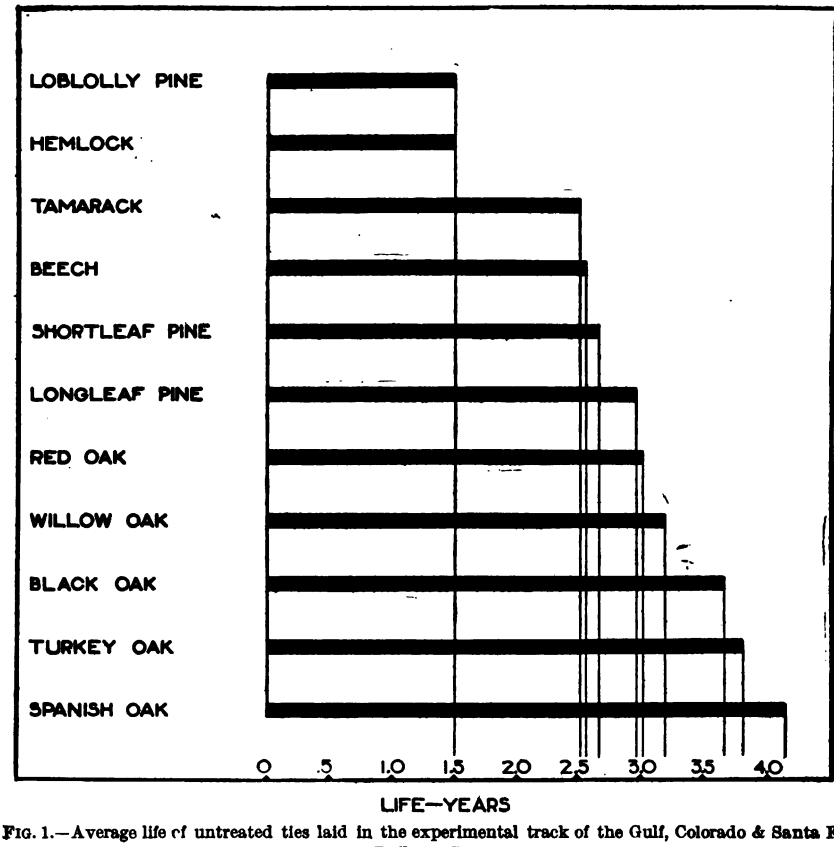

FIG. 1.—Average life of untreated ties laid in the experimental track of the Gulf, Colorado & Santa Fe Railway Co.

oil in combination with zinc chloride (Table 10) also produced an effective treatment.

(4) Treatment with preservatives will not yield good results unless the ties are sound in the first place and the treating is properly done. This is strikingly shown by the treatments with zinc chloride and English creosote (Table 11). These ties were probably injured by oversteaming during the treatment.

(5) The great variation in durability of the different species in nearly all of the treatments indicates that some of the species were

not properly treated, and emphasizes the necessity of separate treatments for each species.

(6) Species which, when untreated, decay most rapidly appear to give the greatest relative increase in service when treated. Loblolly

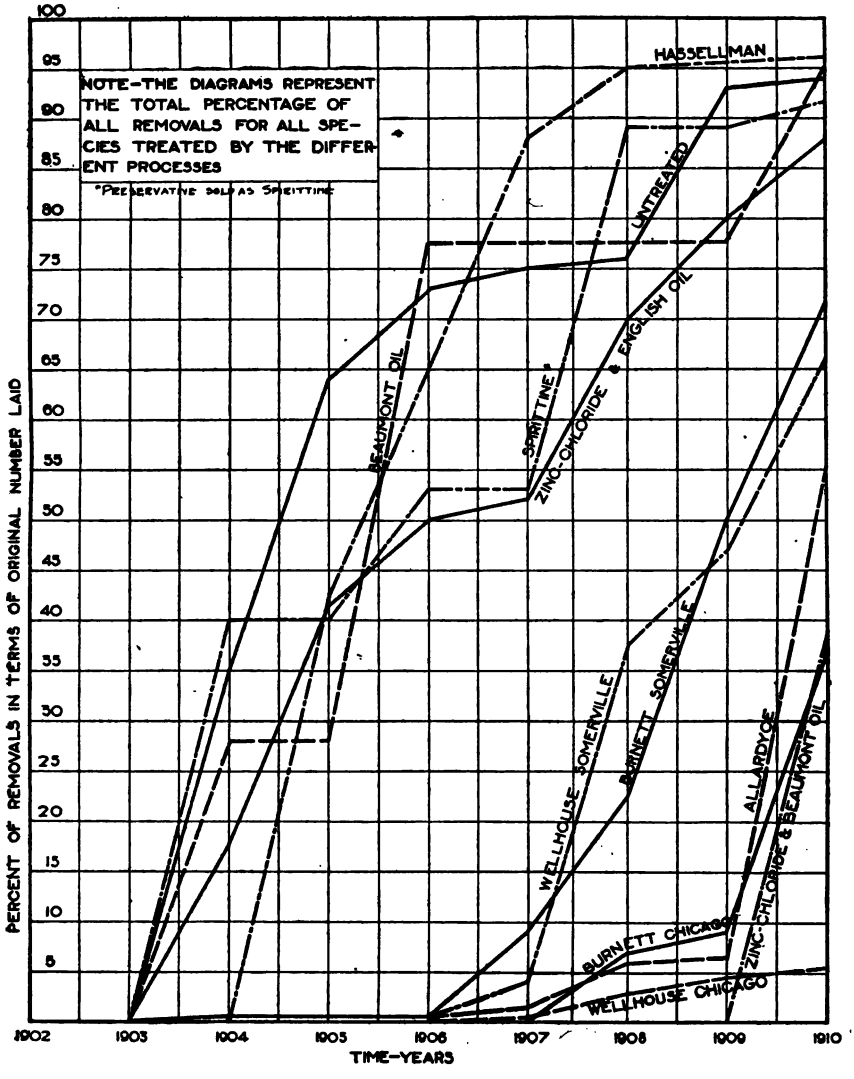

FIG. 2.—Tie removals from the experimental track of the Gulf, Colorado & Santa Fe Railway Co.

pine, hemlock, beech, and tamarack, which are the least resistant to decay when untreated, appear when treated to be about equally as durable as treated longleaf pine, Spanish oak, and white oak.

TEST TRACK LAID IN COOPERATION WITH THE NORTHERN PACIFIC RAILWAY CO., AT PLAINS, MONT.

DESCRIPTION OF TRACK.[1]

The 2,650 7 by 9 inches by 8 feet hewed ties which were placed in the main line of the Northern Pacific Railway Co., about 2 miles west of Plains, Mont., were laid during the summer of 1907 on a tangent with a uniform grade of 0.0167 per cent; the ballast is gravel and the general drainage conditions of the track are good. The line is single track and traffic is heavy. New 85-pound rail was laid when the ties were placed, with the exception of a small portion of the track which was changed at a later date. Several forms of tie-plates and both cut and screw spikes were used.

OBJECTS OF THE TEST.

This test was designed chiefly to secure information as to:

(1) The durability of green and air-seasoned untreated Douglas fir and western larch ties.

(2) The durability of burnettized Douglas fir and tamarack ties.

(3) The efficiency of the flanged, flat, and wooden tie-plates when used with cut or screw spikes.

TREATMENT.

The Burnettized ties were treated by the Great Northern Railway Co. in its plant at Somers, Mont. A 6 per cent solution was used, and the gauge readings showed an injection of 0.786 pound of dry zinc chloride per cubic foot. Both species were treated in the same charge and larch absorbed about 10 pounds of solution more per tie than the Douglas fir.

RESULTS.[2]

The track was inspected by the Forest Service in 1909, 1910, and 1911, the latest inspection being about four years after the ties were placed. The inspections yielded the following results:

(1) None of the ties showed any marked difference in their relative durability.

(2) Douglas fir ties were not checking as badly as the western larch ties.

(3) Ties treated with zinc chloride were more rail-worn than untreated ties of the same species.

[1] For a more complete description see Forest Service Circular 146, "Experiments with Railway Crossties," by H. B. Eastman.

[2] From the reports of H. B. Oakleaf, Forest Assistant, and P. R. Hicks, Engineer in Forest Products, who made the inspections for the Forest Service in conjunction with officials of the Northern Pacific Railway Co.

(4) Untreated larch ties were more rail-worn than untreated Douglas fir ties, but were not as badly worn as the treated ties of either species.

(5) The flat metal plates were causing the ties less damage than any of the other plates used.

(6) Flanged tie-plates caused more checking and brooming than flat ones.

(7) The wooden plates did not prove serviceable, as they worked out from under the rail and split badly; moreover, they did not prevent wear of the ties.[1] They were removed during 1910 and replaced with metal plates.

(8) Because of lack of support under the head, the screw spikes tended to become bent by the lateral thrust of the rail.[1]

TEST TRACK LAID IN COOPERATION WITH THE NORTHERN PACIFIC RAILWAY CO. AT MAYWOOD, WASH.

DESCRIPTION OF TRACK.[2]

The 2,280 7 by 9 inches by 8 feet sawed ties which were placed in the main line of the Northern Pacific Railway Co. near Maywood (about 6 miles west of Hot Springs), Wash., were laid in the fall and winter of 1906–7. Two curves, one of 2° and the other of 5°, are included in this track. The grade varies from 0.46 to 0.96 per cent. The roadbed for the most part is an earth embankment well drained; gravel ballast is used exclusively. The track is laid with 72-pound rail; the traffic is exclusively heavy, and loaded trains pass in both directions. Screw spikes are used on a part of the track, both with and without tie-plates, and in various combinations with cut spikes.[3]

OBJECTS OF THE TEST.

The test was designed to yield information on the following points:

(1) The durability of green and air-seasoned untreated Douglas fir and western hemlock ties.

(2) The durability of creosoted Douglas fir ties.

(3) The efficiency of flat tie-plates in preventing wear and the relative efficiency of screw and cut spikes as rail fastenings.

TREATMENT.

Four hundred and fifty air-seasoned Douglas fir ties were treated by the full-cell creosote process in the plant of the Pacific Creosoting

[1] For discussion and illustration of this, see Forest Service Bulletin 118, "Prolonging the Life of Cross-Ties."

[2] For a more complete description, see Forest Service Circular 146.

[3] At the time this track was laid no spike-boring machine was available and the holes for the screw spikes were bored by hand. In some cases the holes were not bored deep enough and when the screw spikes were inserted they hit the bottom of the holes and on subsequent tightening stripped the threads in the wood. It is felt that a fair test is not being given to the screw spikes in this track.

Co. at Eagle Harbor, Wash. The ties were weighed before and after treatment, and again 90 days later. The increase in weight during treatment was 8.6 pounds per cubic foot. After 90 days air seasoning an average of 2.4 pounds of this increase had been lost, leaving the net increase 6.2 pounds per cubic foot.

RESULTS.[1]

The latest inspection of these ties was made by the Forest Service in June, 1911, approximately four and one-half years after placement. Following is a summary of the observations made:

(1) The green, untreated hemlock ties were beginning to deteriorate quite rapidly. Many of them had wood-destroying fungi growing upon them.

(2) The Douglas fir ties seemed to be better than the hemlock as far as checking, rail wear, brooming, and decay were concerned.

(3) The creosoted Douglas fir ties were decidedly more rail cut than the untreated ties.

TEST TRACK LAID IN COOPERATION WITH THE CHICAGO & NORTH WESTERN RAILWAY CO.

DESCRIPTION OF TRACK.

The 3,040 6 by 8 inches by 8 feet hewed ties placed in the main line of the Chicago & North Western Railway Co. near Janesville, Wis., were laid in December, 1907, on a level tangent. A change in the lines of the company subsequent to laying the ties has caused the traffic over the track to be very light, consisting only of passenger trains in one direction. The track is laid with 90-pound rail in well-drained gravel ballast.

OBJECTS OF THE TEST.

The test was designed to secure information as to:

(1) The natural durability of eastern hemlock and tamarack ties.

(2) The comparative efficiency of the Burnett, Wellhouse, and open-tank creosote processes.

(3) The comparative efficiency of flat and flanged metal ties-plates and creosoted wooden plates and of cut and screw spikes used with treated ties.

TREATMENT.[2]

The ties were treated with zinc chloride at the plant of the Chicago & North Western Railway Co. at Escanaba, Mich., by both the Bur-

[1] From the reports of H. B. Oakleaf, Forest Assistant, and P. R. Hicks, Engineer in Forest Products, who made the inspections for the Forest Service in conjunction with officials of the Northern Pacific Railway Co.

[2] For a more complete description of the treatments see Forest Service Circular 132, "The Seasoning and Preservative Treatment of Hemlock and Tamarack Cross-Ties," by W. F. Sherfesee.

nett and Wellhouse processes. A 4 per cent solution was used, and the injection averaged about 12 pounds of solution per cubic foot. Some of the ties were given an open-tank treatment with coal-tar creosote and absorbed about 15 pounds per tie. The record of absorption of each tie is on file with the Forest Service, and as the ties begin to fail the relation of the absorption to the failure will be studied.

RESULTS.

The latest inspection of this track was made by the Forest Service in May, 1911. Table 12 shows the condition of the untreated ties at that time, after about three and one-half years' service. Approximately 15 per cent of the untreated hemlock and 13 per cent of the untreated tamarack ties were so badly decayed that they were unserviceable; in addition, about 8 per cent of the hemlock and 30 per cent of the tamarack were less seriously affected with decay.

The following additional observations were made:

(1) Only two of the treated ties showed any evidence of decay.

(2) About 44 per cent of the hemlock and 60 per cent of the tamarack ties which were untreated and unprotected by plates were rail cut to a depth varying from one-fourth to one-half inch and practically all showed rail wear to some extent.

(3) There was no apparent difference in the condition of the ties equipped with flat plates and cut spikes and those having flat plates and screw spikes. In both cases when the surface of the tie was uneven there was some plate wear, the maximum being about one-fourth inch.

(4) Many of the flanged plates were still only partially embedded in the ties and gravel was found under a good many of them. As a result, some of the plates were bent and twisted.

(5) The damage to the ties with wooden plates appeared to be less than to those otherwise protected, but some of the plates were missing and many were split and damaged to some extent. It appears, therefore, from this and other experiments, that the successful use of wooden plates depends largely on the frequency of their inspection and replacement.

(6) Lack of support under the outer portion of the head of the screw spikes had, in some cases, resulted in the spikes bending outward from the rail. This effect is greater with the wooden plates than with any of the others.[1]

[1] This is discussed and illustrated in Forest Service Bulletin 118, "Prolonging the Life of Cross-Ties."

TABLE 12.—*Condition of untreated ties in the test track of the Chicago & North Western Railway Co. after three and one-half years' service.*

Lot No.	Species.	Time seasoned.	Season cut.	Condition while seasoning.	Number of ties.	Condition as found on inspection.			
						Good.	Partially decayed.	Decayed.	Worn.
		Months.				*Per ct.*[1]	*Per ct.*[1]	*Per ct.*[1]	*Per ct.*[1]
57	Hemlock...	29	Summer..	Peeled and soaked for few days prior to seasoning.	20	50	10	20	20
58	.....do.....	28	.....do.....	Peeled.....	20	45	10	.....	45
59	.....do.....	26	Fall.....	.....do.....	20	45	.....	15	40
60	.....do.....	23	Winter....	.....do.....	20	65	5	15	20
61	.....do.....	26	Fall.....	.....do.....	20	35	.....	25	40
62	.....do.....	35	Winter....	.....do.....	20	20	10	40	40
63	.....do.....	11	.....do.....	Unpeeled on two sides.	50	26	14	4	66
	Total.....	.....	.....	.....	170	37.6	8.2	14.7	43.5
64	Tamarack..	23	Winter....	Peeled.....	25	16	24	20	56
65	.....do.....	23	.....do.....	Unpeeled on two sides.	25	32	16	4	60
66	.....do.....	35	.....do.....	Peeled.....	20	35	15	10	70
67	.....do.....	11	.....do.....	Unpeeled on two sides.	62	14.5	37	14.5	58
	Total.....	.....	.....	.....	132	19.7	29.5	12.9	59.8

[1] Based on number of ties originally placed.

TEST TRACK LAID IN COOPERATION WITH THE INDIANAPOLIS, COLUMBUS & SOUTHERN TRACTION CO.

DESCRIPTION OF TRACK.

The 945 6 by 8 inch by 8 feet hewed ties laid in cooperation with the Indianapolis, Columbus & Southern Traction Co. were placed in September, 1909, in the main line of this company near Taylorsville and Edinburg, Ind. With the exception of a few ties which are placed in a sharp curve, all are in an approximately level tangent. The roadbed is fairly well drained; the ballast is gravel containing some sandy soil. The track is laid with 65-pound rail without tie-plates and with ordinary cut spikes. Traffic is light, and is confined to interurban electric cars.

OBJECTS OF THE TEST.

The test was designed to secure information on the comparative efficiency of red and black oak ties treated with coal-tar creosote (full-cell process), zinc creosote, and "asphaltic crude oil,"[1] using low pressures.

TREATMENT.

The ties used in this track were treated in the low-pressure wood-preserving plant of the Indianapolis, Columbus & Southern Traction Co. All were thoroughly air seasoned. Those treated with creosote

[1] This preservative was contributed for the experiment by the Indian Refining Co., of Cincinnati, Ohio.

were boiled in the oil at a temperature not exceeding 225° F. from one to four hours, after which a pressure not exceeding 45 pounds per square inch was applied until the desired absorption was obtained. Those treated with creosote and zinc chloride were first heated in creosote for one hour at a temperature varying between 200° and 212° F., after which they were impregnated with a 4½ per cent solution of zinc chloride under a pressure of not more than 45 pounds per square inch. In the treatments with "ashphaltic crude oil" the injection was very light. On account of the viscous nature of the oil it was not possible to apply pressure exceeding 20 pounds per square inch with the apparatus used. Table 13 shows the character of treatment given the ties placed in this test.

TABLE 13.—*Condition of treated red oak ties in the test track of the Indianapolis, Columbus & Southern Traction Co. after two years' service.*

Character of treatment.		Total number of ties.	Condition as found on inspection.			
Preservative.	Absorption (per cubic foot).		Good.	Partially decayed.	Split.	Worn.
			Per cent.[1]	*Per cent.*[1]	*Per cent.*[1]	*Per cent.*[1]
Coal-tar creosote....	About 14 pounds maximum absorption.	99	83.9	2	14.1	.....
Do.....	12 pounds.....	53	86.9	.....	11.3	1.8
Do.....	7 to 8 pounds.....	429	94.4	.....	5.6	.....
Creosote and $ZnCl_2$.	0.46 to 0.55 pound $ZnCl_2$, 3 to 4 pounds creosote.	198	84.4	12.1	5	.5
Asphaltic crude oil.	Indeterminate, but very slight.	167	86.2	.....	13.8	.....

[1] Based on number of ties originally placed.

RESULTS.

The latest inspection of ties was made by the Forest Service in September, 1911, two years after placement. Table 13 shows their condition at that time. Following is a summary of the observations made:

(1) No badly decayed ties were found, although approximately 2 per cent of those treated with about 14 pounds of creosote per cubic foot and approximately 12 per cent of those treated with creosote and zinc chloride were slightly affected with decay. This is probably due to the fact that some of the ties were affected at the time of treatment.

(2) A number of the ties of each treatment were more or less split on the ends. In practically all such cases, however, the exposed portions of the ties appeared thoroughly sound and well treated, and it is probable that the greater part of the splitting existed at the time of treatment.

(3) Only two of the ties showed any rail wear, and this was so slight as to be negligible.

TEST TRACK LAID IN COOPERATION WITH THE TENNESSEE COAL, IRON & RAILROAD CO.

DESCRIPTION OF TRACK.

The 920 7 by 9 inches by 8 feet sawed ties placed in cooperation with the Tennessee Coal, Iron & Railroad Co. were laid in the spring of 1910 in a portion of the track of the Birmingham Southern Railroad Co. just south of the steel plant of the company at Ensley, Ala. Most of the ties are in a tangent. Slag is used for ballast. The roadbed is level and drainage is poor. Seventy-pound rail is used, with ordinary cut spikes. At first pronged tie-plates were used only on curves, but about one year later these were placed on all ties. The traffic consists of heavily loaded ore cars.

OBJECTS OF THE TEST.

The test was designed to secure information as to:

(1) The natural durability of longleaf pine and white-oak ties.

(2) The comparative efficiency of "cresol-calcium"[1] and coal-tar creosote in protecting shortleaf pine, loblolly pine, and red-oak ties from decay when treated by the low-pressure process.

TREATMENT.

The treatments were made at the plants of the Tennessee Coal, Iron & Railroad Co. near Birmingham, Ala. The shortleaf and loblolly pine ties which were treated with creosote received an injection of 7 pounds of oil per cubic foot of wood, injected under a pressure of not more than 40 pounds per square inch. In the cases of the red-oak ties treated with creosote and the pine ties treated with cresol-calcium, a vacuum of about 10 inches was first drawn and the preservative was then admitted to the cylinder; a pressure of from 10 to 15 pounds per square inch was applied until the desired absorption was secured. Table 14 shows the number of ties of each class placed in this track and the treatment given each lot.

RESULTS.

An inspection of this track was made about six months after it was placed. All of the ties were sound and free from wear.

[1] This preservative was contributed by Messrs. Blagden, Waugh & Co., London, England.

TABLE 14.—*Treatment given ties used in the Tennessee Coal, Iron & Railroad Co. test track.*

Species.	Preservative.		Absorption.	Tie numbers.
	Kind.	Strength of solution.		
		Per cent.	*Lbs. per cu. ft.*	
Shortleaf and loblolly pine	Cresol-calcium	9.7	[1] 1.15	5–108
Do	do	7.5	[1] 0.85	109–213
Do	do	5.0	[1] 0.51	214–315
Do	do	2.5	[1] 0.27	316–417
Red oak	Creosote		5.54	622–722
Shortleaf and loblolly pine	do		7.0	418–621
Longleaf pine	Untreated			824–924
White oak	do			723–823

[1] Dry salt.

TEST TRACK LAID BY THE WENATCHEE VALLEY & NORTHERN RAILWAY CO.

The Wenatchee Valley & Northern Railway Co. placed 100 test ties in the main line of its track near Delmont, Wash., in July, 1910. The ties were hewed on two faces, the bark being left on the sides, and were air seasoned for approximately one year before they were placed in the track. Sixty-pound rail and cut spikes were used. The roadbed is a slight fill with good drainage ditches on both sides; the ballast is a light sandy loam; the grade is 2 per cent. Traffic over the line is light.

The information to be secured from this track is data on the comparative durability of untreated hewed ties of Douglas fir, western yellow pine, lodgepole pine, and grand fir. The ties have not been placed sufficiently long to furnish any results.

TEST TRACK LAID IN COOPERATION WITH THE CHICAGO, MILWAUKEE & ST. PAUL RAILWAY CO.

DESCRIPTION OF TRACK.[1]

The test ties placed in the main line of the Chicago, Milwaukee & St. Paul Railway Co. near Hartford, Wis., were laid in August, 1911. Seventeen hundred and eleven hewed and sawed 6 by 8 inches by 8 feet ties constitute the test. The ties are placed in a level tangent on a well-drained roadbed. Gravel is used for ballast; traffic is fairly heavy, and trains pass over the line in both directions; new 90-pound rail was laid. In general, one-half of these ties are plated with flat steel plates having boss under the spike heads, and screw spikes are used; the rest are unplated and the rail is fastened with cut spikes. Malleable iron ribbed plates (with cut spikes) are used on a few of the ties.

[1] A full description of this track and a record of the treatment given the ties is found in Forest Service Bulletin 126, "Experiments in the Preservative Treatment of Red Oak and Hard Maple Cross-Ties," by F. M. Bond.

OBJECTS OF THE TEST.

The test should yield information as to—

(1) The natural durability of red oak and hard maple ties.

(2) The efficiency of the Burnett, Card, zinc-creosote, full-cell creosote, Rueping, and crude-oil treatments in protecting red oak and maple, and the kyanizing process in protecting spruce ties from decay.

(3) The efficiency of flat-bottom plates when laid with screw and cut spikes in protecting ties from mechanical wear.

TREATMENT.

All of the treated ties were impregnated at the Forest Products Laboratory with the exception of 262 burnettized red oak, 21 burnettized chestnut, and 25 kyanized spruce ties,[1] which were treated at commercial plants and added to the experiment that was originally planned. Complete records of the ties treated at the Forest Products Laboratory are available,[2] and these include treatment records for each charge, the absorption of each tie, its moisture content at the time of treatment, volume, oven-dry weight of the wood, and other characteristics which might have affected the behavior of the tie under treatment or its durability. A list of the ties placed, with the character of treatments applied to the various lots, is given in Table 15.

The track has not been in existence sufficiently long to furnish any results.

TABLE 15.—*Manner in which the ties in the Chicago, Milwaukee & St. Paul test track were treated and laid.*

Kind of wood.	Process.	Preservative.		Ties laid.	Ties plated.	Numbering nails.
		Kind.	Amount injected.			
			Lbs. per cu. ft.	*Number.*	*Number.*	
Red oak	Full-cell	Creosote	10.9	102	52	[3] 101–200
Do	Rueping	do	5.3	100	50	1–100
Do	Burnett	Zinc chloride	[4] ½	100	50	201–300
Do	do.[5]	do	[4] ½	262	262	[6] 1301–1400 2001–2154
Do	Card	Zinc chloride and creosote	[7] 15.3	100	50	1201–1300
Do	Two-movement	do	[8] 15.3	100	50	801–900
Do	Full-cell	Semirefined oil, paraffin base	7.3	100	50	601–700
Do	Untreated			100	50	701–800
Hard maple	Full-cell	Creosote	12.0	100	50	501–600
Do	Rueping	do	4.9	100	50	401–500
Do	Burnett	Zinc chloride	[4] ½	100	50	301–400
Do	Card	Zinc chloride and creosote	[7] 16.0	100	50	1101–1200
Do	Two-movement	do	[8] 15.5	100	50	1001–1100
Do	Full-cell	Semirefined oil, paraffin base	12.6	100	49	1401–1500
Do	Untreated			100	50	1501–1600
Spruce	Kyanized[5]	Mercuric chloride		25	13	901–925
Chestnut	Burnett[5]	Zinc chloride	[4] ½	21	21	[9] 926–947

[1] The kyanized spruce ties were contributed by the Berlin Mills Co., of Manchester, N. H.
[2] Forest Service Bulletin 126.
[3] Two ties with subnumbers.
[4] Dry salt.
[5] Treated at commercial plant.
[6] Eight ties with subnumbers.
[7] Emulsion.
[8] Mixture.
[9] One number missing.

SUMMARY.

Since 1902 the Forest Service has constructed eight test tracks in cooperation with seven different railroad organizations. Because a long time must elapse before data can be obtained on durability, few of these tracks have thus far yielded conclusive results. The information already received indicates that test tracks, if properly constructed and inspected, prove a valuable index in showing economies in track maintenance.

So far as can be told by present results, all treatments, with one exception, have increased the durability of the ties over that of similar untreated material. Just how much the natural life of the ties can be prolonged is not yet determined, but that it may in many cases be doubled or even trebled seems certain. For example, untreated loblolly pine and hemlock ties laid in Texas lasted only 1.5 years, while of those burnettized over 70 per cent were still serviceable after seven years.

Ties with low decay resistance, such as loblolly pine, hemlock, tamarack, and beech, if laid untreated, should not be tie-plated, as they will decay before they will wear out.

The increased resistance to decay secured from preservative treatment makes it highly desirable to protect treated ties from deterioration by mechanical cause. This is particularly true of ties with low-crushing strength.

Experience thus far is not conclusive as to the best form of plates to use. Wooden plates, when simply laid under the rail, have not proved satisfactory, as they either become loose, split, or, in some cases, become embedded in the tie. Flanged metal plates have a decided tendency to split the tie, thus forming cracks which enable moisture to reach the interior and hasten decay. Metal plates with flat or slightly corrugated bottom have thus far given the best results.

Service tests on screw and cut spikes have, to the present time, yielded no definite conclusions. It has been shown, however, that when screw spikes are used it is desirable to have some form of boss on the plates to reenforce the heads of spikes against lateral thrust.

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FOREST SERVICE—Circular 210.
HENRY S. GRAVES, Forester.

YIELD AND RETURNS OF BLUE GUM
(EUCALYPTUS)
IN CALIFORNIA.

BY

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WASHINGTON:
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YIELD AND RETURNS OF BLUE GUM (EUCALYPTUS) IN CALIFORNIA.

INTRODUCTION.

Interest in eucalyptus culture is steadily increasing. There is a corresponding demand for information on the yield of plantations as a basis for determining their financial returns. It is the aim of this circular to show what may be expected from blue-gum plantations in California under favorable conditions.

In order to secure reliable figures on the yield of eucalyptus the Forest Service, in cooperation with the California State Board of Forestry, measured in 1910 a large number of the most successful eucalyptus plantations in California. Most of these measurements were of blue gum (*Eucalyptus globulus*), the species most extensively planted. Of the many species of eucalyptus it is the one which seems best adapted to California conditions, and it is also one of the most rapid growing. The results of this work have been published in Bulletin 1, California State Board of Forestry, under the title "Yield from Eucalyptus Plantations in California," which may be obtained without cost from the State Forester, Sacramento, or from the Forest Service, San Francisco. The best figures obtained in this study, together with known costs of establishing and caring for plantations, are here summarized.

COST OF ESTABLISHING PLANTATIONS.

The first item to be reckoned with in the establishment of a plantation is the cost of land. The better the land the more satisfactory, up to a certain point, will be the returns. Good irrigable land near transportation, however, is in great demand for the raising of farm crops, and its price is correspondingly high. Moreover, such land yields large annual returns under diversified crops, and its most profitable use is not the growing of trees. Stiff, heavy, loamy or sandy, nonirrigable lands free from hardpan, such as are suitable for grain farming, with a water table not more than 12 feet below the surface, are usually well adapted to blue gum. Such areas in desirable localities, that is, near transportation and where the mini-

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mum temperature is not less than 24° F., can be purchased for about $30 per acre.

The cost of preparing an acre of ground for planting does not ordinarily exceed $6. Seedlings can be purchased for $6 per thousand. The planting of 1,000 trees (enough for an acre) costs about $4. The cost of cultivating and caring for a plantation for two years does not usually exceed $7 per acre, including the purchase of trees to fill blanks in the plantation. Any thinnings made up to the time of the first cutting should pay for themselves. The cost of establishing a plantation and carrying it through the first two years, excluding the cost of land, is therefore about $23 per acre.

Taxes on the class of land used for growing blue gum amount to about 30 cents per acre per year. Ten cents per acre per year should be expended in protection from fire. These two items represent a fixed annual charge per acre for the 10-year period before the first cutting. Discounted at 4 per cent, this amounts to a present investment of about $3.25 per acre.[1] The total investment involved in establishing 1 acre of plantation is, therefore, about $56.25.

YIELDS OF PLANTATIONS.

Actual measurements show that an average annual yield of about 6.4 standard cords, or 8.5 California cords, per acre is produced by the best blue-gum groves in the State.[2] This figure was obtained by finding the mean annual growth per acre of all the groves examined in 1910 which contained over 5 standard cords, and then determining the average of 20 per cent of the groves showing the most rapid mean annual growth.[3] It was thus based upon the best 5 of the 25 groves examined. While not strictly accurate, since the rate of growth of trees varies somewhat at different ages, it is sufficiently so for practical purposes in this instance, where the range in ages is not great. Individual groves have occasionally done better. One grove was found which produced 185.9 standard cords in 25 years, or about 7.4 cords per year. Another produced over 59 cords in nine years, or nearly 6.6 cords per year. On the other hand, three groves under average conditions, with fair soil and the water

[1] This is derived from the formula giving the present value of an amount spent annually for a given number of years, $E = \frac{r\ (1.0\ p^n - 1)}{(1.0\ p^n \times .\ op.)}$, in which E=present value of the charges for taxes and protection; r=annual tax and protection charge ($0.40); p=rate of interest (4 per cent); and n=number of years (10). The present value of the charges for taxes and protection is the amount which, invested at the given rate of interest, will meet these charges annually, and will be exhausted at the end of the period.

[2] A standard cord contains 128 cubic feet of stacked wood, or approximately 90 cubic feet of solid wood; a California cord, the local unit, is three-fourths of a standard cord and consequently contains 96 cubic feet of stacked wood, or approximately 67.5 cubic feet of solid wood.

[3] Bulletin 1, California State Board of Forestry, pp. 12–14.

table not more than 25 feet from the surface, show an annual growth per acre of only 4.05, 3.9, and 3.7 cords, respectively. Under unfavorable conditions, with a deep water table or with hardpan near the surface, the annual growth in two cases has been as low as 1.6 cords and 1.1 cords per acre. An annual yield of 6.4 cords per acre, or 64 cords per acre in 10 years, may therefore be accepted as a fair estimate of what may be obtained upon the best sites under the methods of management heretofore used.

Assuming a stumpage price of $2.50 per standard cord, this yield would return $160 in 10 years from the wood alone. This represents nearly 13 per cent compound interest on the original investment of $56.25.[1] Out of that amount $30, the cost of the land, may be considered as restored to the investor with the harvesting of the crop, and is in effect an additional return.

Since blue gum sprouts rapidly, the same return of 64 cords, worth $160, should be obtained periodically at the end of every 10 years for at least several rotations. In this case, however, no additional expenditure is necessary for establishing or caring for the plantation. The amount invested is, therefore, $33.25 ($30 for land and $3.25 for capitalized taxes and protection). A return of slightly more than 19 per cent would thus be realized in growing each of the sprout crops following the first, or planted crop. This is assuming that the value of the land remains unchanged and that this amount is reinvested periodically after each crop is harvested.

In the figures just given it is assumed also that the operation is handled by the individual investor on an area large enough to be managed economically. This should be not less than 50 acres.

The greatest yield of any blue-gum grove measured by the Forest Service was found in a plantation 32 years old. This stand contains 57,820 board feet of timber per acre, measured by the Scribner Decimal C log rule, besides 30.9 standard cords (41.2 California cords) of wood to be cut from tops too small for lumber. Assuming a stumpage rate of $5 per thousand feet for lumber and $2.50 per standard cord, the return on this grove would amount to $366.35 per acre for the 32-year period. If it costs $60.15 per acre (on the same basis as that used above) to buy and plant the land, care for the young trees two years, and pay taxes and protection charges 32 years (discounted to the present at 4 per cent), the return is a little over 6 per cent com-

[1] This is derived from the well-known valuation formula $Y=(C+E)\times 1.0p^n+S(1.0p^n-1)$, in which Y=yield at end of rotation ($160); C=cost of establishing and caring for plantation ($23); E=capitalized expenses for taxes and protection ($3.25); S=cost of land ($30); n=length of rotation (10 years); and p=rate of interest. The −1 in the formula is due to the fact that the value of the land at the end of the rotation is assumed to be the same as at the beginning, so that interest alone is lost on the money invested in land.

pounded.[1] If the stumpage values are $10 for saw timber and $2.50 for cordwood the return per acre would amount to $655.45, or nearly 8 per cent on the same investment.

A grove in Alameda County shows a yield of 54,200 board feet of timber and 43.3 standard cords (57.8 California cords) per acre in 25 years. Assuming a stumpage rate of $5 per thousand for the timber and $2.50 per standard cord for the wood, the return from this grove would be $379.25 per acre for the 25-year period,[2] the cost of land, planting, etc., being figured as before. This would net about 8 per cent compounded. If the stumpage price is $10 per thousand for saw timber and $2.50 per cord for the limb wood, the return per acre would amount to $650.25, a little over 10 per cent on the investment.

The stumpage figures used are mere assumptions. It is probable that but a small part of the timber produced in any of these groves could be sold for lumber at the present time. Most of the trees are between 10 and 12 inches in diameter at 4½ feet from the ground. There is as yet but little demand for eucalyptus of such small dimensions for manufacture into lumber.

Of California eucalyptus as lumber little is known. Up to the present time but small quantities have been manufactured. A few well-developed old trees, which have grown in the open and are unusually large, are sold for high prices. No sales of entire groves for lumber have been made, however, since most of the trees are still too small or too crooked and limby to be sawed at a profit. In Australia no eucalyptus goes into the sawmill from trees less than 30 years old or 2 feet in diameter, since lumber from young trees warps and shrinks badly, resulting in great waste.[3]

In every young grove, however, a number of trees have outstripped their neighbors in form and size. In the management of a plantation it will probably be found profitable to cut the less desirable trees for cordwood at the end of about 10 years, leaving from 150 to 200 of the best trees on each acre to grow to saw-timber size, at 30 or 40 years. In that form they should bring a larger return per unit of volume than as cordwood. Moreover, as the problem of seasoning small California-grown eucalyptus is worked out, and as manufacturers become more familiar with the handling of this wood, a demand for it will arise and doubtless lead to the establishment of more definite stumpage values. Investigations by the Forest Service to determine the best method of seasoning blue gum by kiln drying were completed and will soon be published.

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[1] See footnote on p. 5. The costs for land and for establishment and care of the plantation are the same as before, but the present value of taxes and fire protection is $7.15 on account of the longer period.

[2] See footnote on p. 5. In this case the present value of taxes and fire protection amounts to $6.25.

[3] Forest Service Circular 170, p. 28.

WHAT RETURNS CAN BE EXPECTED UNDER MOST FAVORABLE CONDITIONS.

Much greater yields and higher financial returns have been claimed for eucalyptus plantations by commercial companies which are exploiting them. Planted land has been offered in many instances as a desirable investment at as much as $250 per acre. It has been asserted that an acre of planted eucalyptus will produce 100,000 board feet of lumber in 10 years.

Measurements of existing groves by the Forest Service show, however, that the best return per acre which can be expected from a 10-year plantation of blue gum, under present conditions, is approximately $160. If the original investment does not exceed $60, including taxes and protection, until the crop is cut this return is satisfactory. If the investment is greater than $60 per acre, on account of planting higher-priced land or for other reasons, the returns are correspondingly reduced. If the total amount paid out exceeds $160 per acre, obviously there is a loss of capital aside from the failure to secure any interest upon it.

These measurements show, furthermore, that the best blue-gum groves in California have yielded but 64 standard cords (85 California cords) per acre in 10 years. The yield must be given in cordwood rather than in board feet of lumber. The trees in these plantations have attained an average diameter of from 9 to 10 inches outside the bark at 4.5 feet above the ground. Since the bark is 0.75 of an inch thick, about 1.5 inches must be deducted from the diameter to obtain the net yield of wood. The taper of blue-gum logs, determined by actual measurements, is 0.163 of an inch per foot. The top diameter of a log 12 feet long and 10 inches in diameter outside the bark at 4.5 feet above the ground (allowing 12 inches for the height of the stump) is 7.12 inches inside the bark. Such a log, when measured by the Scribner Decimal C rule, scales 20 board feet. It has been found that young timber of this character shrinks about 14 per cent in seasoning to an air-dry condition, and that the wood contains loose knots left by the branches. From this it is apparent that only small timbers suitable for short-length flooring, chair legs, handles, etc., can be obtained from trees of this size. Such trees can hardly be considered as merchantable for manufacture. The chief product of a 10-year eucalyptus grove, therefore, is not lumber but cordwood.

The best 32-year-old plantation in the State scales but 57,820 board feet and 30.9 cords per acre. It is true that none of the older groves in California have been properly thinned or otherwise cared for, and that better management undoubtedly will increase the yield, at least of saw timber. To what extent such management will increase the total yield of plantations has not been demonstrated and can be worked out only by experience. It should be borne in mind,

however, that nowhere in the history of the world has any such quantity of wood as 100,000 board feet been produced per acre in 10 years. There is a limit to the productiveness of even the best land under the best conditions of management. This limit, as far as intensive forest culture has yet demonstrated, is far below 100,000 board feet in a decade. Barring redwood, bigtree, Pacific coast Douglas fir, and virgin stands of eucalyptus in Australia, it is but rarely that forests anywhere produce this quantity of material per acre in one crop, regardless of the element of time.

The investigations made by the Forest Service indicate, therefore, that returns from blue-gum plantations are satisfactory if the total investment is $60 an acre or less; that in proportion as the initial investment and discounted carrying charge exceed this amount, the prospects of a good profit are reduced, and that an investment approaching $160 per acre can not be expected to pay back more than the bare principal. Satisfactory results can ordinarily be secured by personally starting and caring for plantations rather than by purchasing planted land at any figure which is out of proportion to the actual cost of establishing the crop.

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HENRY S. GRAVES, Forester.

GREENHEART.

BY

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WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1913.

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GREENHEART.

IMPORTANCE OF THE WOOD.

Greenheart (*Nectandra rodiæi* Schomb.) is a South American and West Indian tree belonging to the laurel family (Lauraceæ), which includes our red bay (*Persea borbonia* (Linn.) Spreng.) and sassafras (*Sassafras sassafras* (Linn.) Karst.). Native Indian names for it are bebeeru, bibiru, supeira, and sipiri. Another name sometimes given it is torchwood, due to the fact that the heartwood of older trees, which is full of oil, burns readily.

The truly remarkable lasting qualities of mature greenheart wood have given the tree a world-wide reputation. Authentic records show that the best grades surpass iron and steel in durability when placed in water or in contact with the soil. This extraordinary freedom from decay is due in part to the presence in the wood of an alkaloid known as biberine,[1] and in part to the presence of resinous substances known as tyloses. These latter consist of reddish-brown masses of parenchymatous (living) cells growing in solid masses within vessel cavities, often completely filling them. As they develop with the growth of the tree they turn dark, sometimes coloring the wood nearly black. It is the extent of their development, and consequently the age of the tree, which in large measure determines the color of the wood,[2] thus giving rise to three varieties—yellow, gray, and black greenheart—recognized in the trade. As might be expected, the black variety is the most durable, since the dark color testifies in general to the abundant development of tyloses.

Next to sugar, greenheart has long been the chief article of export from British Guiana. Its valuable properties first became known to English timber merchants in 1769, and from then on it has been imported in large quantities, first into England and later into the United States. Although already well known, its importance in the timber trade in this country promises to increase, since no other foreign wood is so well adapted to so many important uses.

[1] First discovered in the bark and seeds by Dr. Rodie in 1834. It is now used as a substitute for cinchona. Both the bark and seeds have a market value as sources of supply and are exported in quantity. See "The Technologist," vol. 3, 1863, pp. 140–142.

[2] The dark color of the wood may also in some instances be due to the character of the soil in which the tree grew, since trees growing in wet or dark mucky soil take up highly colored substances, which, in their upward course through the stem of the tree, are deposited on the inner walls of the wood elements.

USES AND DURABILITY.

Greenheart is unsurpassed as a construction timber. It finds its chief use in ship and dock building, especially for keelsons, beams, engine bearers, planking, dock gates, lock gates, piers, and piling. When placed in water it is proof against the ravages of the teredo,[1] and on land it is exempt from the attack of white ants. It has been known to stand in wharves for a period of 30 years, and logs of greenheart which have remained under water for 100 years have kept in perfectly sound condition. All the gates, piers, and jetties of the Liverpool docks and practically all the lock gates of the Bridgewater Canal (England) are of greenheart. It furnished the material, also, for the 50 pairs of lock gates in the Manchester (England) Ship Canal. Indeed, the chief engineer of this canal has asserted that, apart from its practically unlimited durability, greenheart has many advantages over steel for such purposes. It is, in fact, impossible to fix a limit to the durability of lock gates built of greenheart, the only element in their construction which might curtail their length of service being the iron bolts and other fastenings. These, however, can usually be renewed without serious difficulty. When the greenheart dock gates in the Mersey Harbor were removed, in order that the channel might be deepened and widened, the wood originally used in their construction was again employed in building the enlarged gates. Similarly, the wood in the gates of the Canada Dock, built in 1856, was used again in its reconstruction in 1894. The use of greenheart has been specified for sills and fenders in the lock gates of the Panama Canal.

Nansen's ship, *The Fram*, and the Antarctic ship, *Discovery*, were constructed of greenheart. The wood is used also for trestles, bridges, buildings, shipping platforms, staging, millwork, cellar flaps, flooring, wagons, and for all purposes involving great wear and tear. It is highly esteemed as a furniture wood, and is used extensively for carriage shafts. The ends of logs removed in the woods to facilitate snaking are used for such articles as automobile spokes, belaying pins, and tobacco pegs, and for all kinds of turnery. Greenheart and the wood of an associate species known as cumaroo, cumaru, tonquin, tonkabean, or niob (*Dipteryx odorata* Willd.=*Coŭmaroúno odorata* Taubert) have a reputation for fishing rods both in this country and in Europe. The darker grades of greenheart resemble the wood of lignum vitæ (*Guaiacum officinale* Linn.), and are considered an excellent substitute for the latter.

Though exceedingly durable, greenheart tends to split and splinter, and requires great care in seasoning and in working. The logs often cleave at the ends into four segments, but cracks do not usually ex-

[1] It is said that even in tropical waters sea-worms do not penetrate beyond the sapwood.

tend more than 2 or 3 feet from the end. This defect, though serious, is to some extent compensated for by the fact that the logs do not split and form deep shakes along the side in seasoning as do the majority of other woods, so that there is not, after all, more than the ordinary amount of waste in conversion. The wood, moreover, is remarkably free from knots, and generally sound. In addition to its use as timber, great quantities of greenheart are made into charcoal.

DISTRIBUTION.

Greenheart inhabits parts of British, Dutch, and French Guiana, Venezuela, Brazil, Colombia, Peru, Trinidad, Jamaica, and Santo Domingo. It is the most important tree of British Guiana, the only place where it is being cut. There it is found most abundantly along the Essequibo, Demerara, and Berbice Rivers. Much of the best quality of greenheart now marketed comes from Morabelli Creek, a tributary of the Essequibo River, where the tree attains its greatest size and produces the best grade of wood. Greenheart grows along the seacoast and watercourses, seldom extending more than 50 miles inland and never more than 100 miles. It is most plentiful and reaches its best development on a strip between 2 and 3 miles wide just back of the deposit of alluvial soil along the coast and rivers. It seldom grows on sites much above sea level or on clay soil. It can not thrive on rocky soil or on moist hillsides. In British Guiana the southern limit of distribution is marked by the elevated regions. Invariable associates of greenheart are the mora (*Dimorphandra mora* Benth.) and wallaba (*Eperua falcata* Aubl.), though these spread over a much larger area.

LOGGING AND TRANSPORTATION.

The present cost of placing greenheart timber on the market is high. This is the result chiefly of (1) the great expense of logging, due to antiquated methods of extracting the logs and the high cost of hauling them; (2) excessive waste in logging; and (3) high transportation charges.

The present methods of logging greenheart are antiquated, laborious, and expensive. All hauling in the forest is done either by gangs of men or by oxen. Hand labor is employed exclusively in cases where the timber is within a short distance of the place of shipment. Where it is cut on the slopes of hills fronting a navigable stream oxen are used in getting the logs out. Both methods are crude, slow, and wasteful at best.

The timber is not hewed in the careful manner that mahogany, cedar, and many other woods are when prepared for shipment, but goes to market only partially dressed. To facilitate snaking the butts of logs are invariably tapered for 3 or 4 feet from the end, and go to market in this condition instead of being cut off square.

Transportation facilities in the forests of British Guiana are at present exceedingly crude. Only the more accessible parts of the forests in which the choicest greenheart timber is found have as yet been exploited. Besides greenheart, only a few of the better-known timbers, such as wallaba and more recently crabwood (*Carapa guianensis* Aubl.), have been taken. These timbers have been cut along all the principal waterways as far upstream as the falls and rapids which obstruct navigation. The vast and valuable forests of greenheart above the falls are still to be opened up. To exploit the remaining stands of greenheart in British Guiana will, however, require much time and labor. As the vast resources of the country become better known efficient means of transportation to the untouched forest areas in the interior will no doubt be provided.

When greenheart was first exploited $1 per cubic foot was the price usually paid for the timber at the point of shipment. While the present price paid for greenheart is considerably less, the wood now obtained is of an inferior quality, since it is immature and, consequently, less durable. Tracts are now being cut over in some places for the third time, and trees which previously escaped observation or were thought too small to be used are taken. Logs 2 feet in diameter or over yield the best grades. Trees of smaller dimensions have a good deal of sap and are not durable. Their timber, moreover, is likely to shrink and split considerably in seasoning. At present practically all the greenheart timber is shipped to Liverpool and New York. These are the two chief distribution points, and the necessary reshipping of such extraordinarily heavy material approximately doubles the cost of direct shipment.

MARKET.

While the demand for greenheart timber is great, it is not keeping pace with the increased use of fancy cabinet woods and of construction material. The extensive employment of reenforced concrete for wharf construction tends, for one thing, to curtail the output. The volume of native timbers, principally greenheart, exported from British Guiana during the 20 years previous to 1909 is given in the table following:

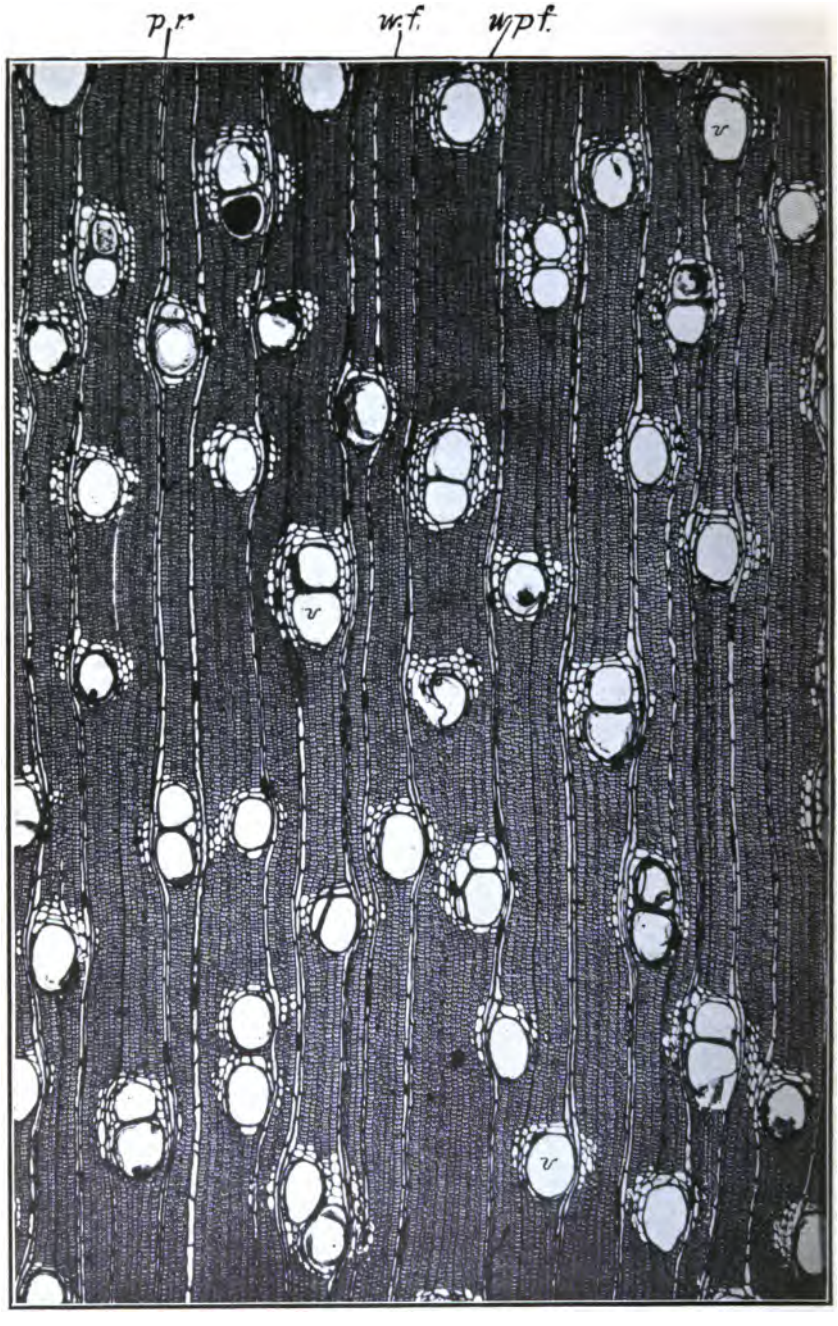
Exports of timber from British Guiana[1] from 1889 to 1909.

Year.[2]	Amount.	Year.	Amount.
	Cubic feet.		*Cubic feet.*
1889–90	296,151	1899–1900	170,632
1890–91	332,098	1900–1901	287,640
1891–92	312,801	1901–2	313,571
1892–93	325,863	1902–3	340,260
1893–94	234,870	1903–4	273,542
1894–95	238,993	1904–5	293,315
1895–96	175,520	1905–6	276,765
1896–97	404,234	1906–7	170,985
1897–98	283,634	1907–8	232,669
1898–99	250,463	1908–9	191,409

[1] Greenheart is exported only from British Guiana and the island of Trinidad.
[2] The fiscal year includes the 12 months from April 1 to March 31.

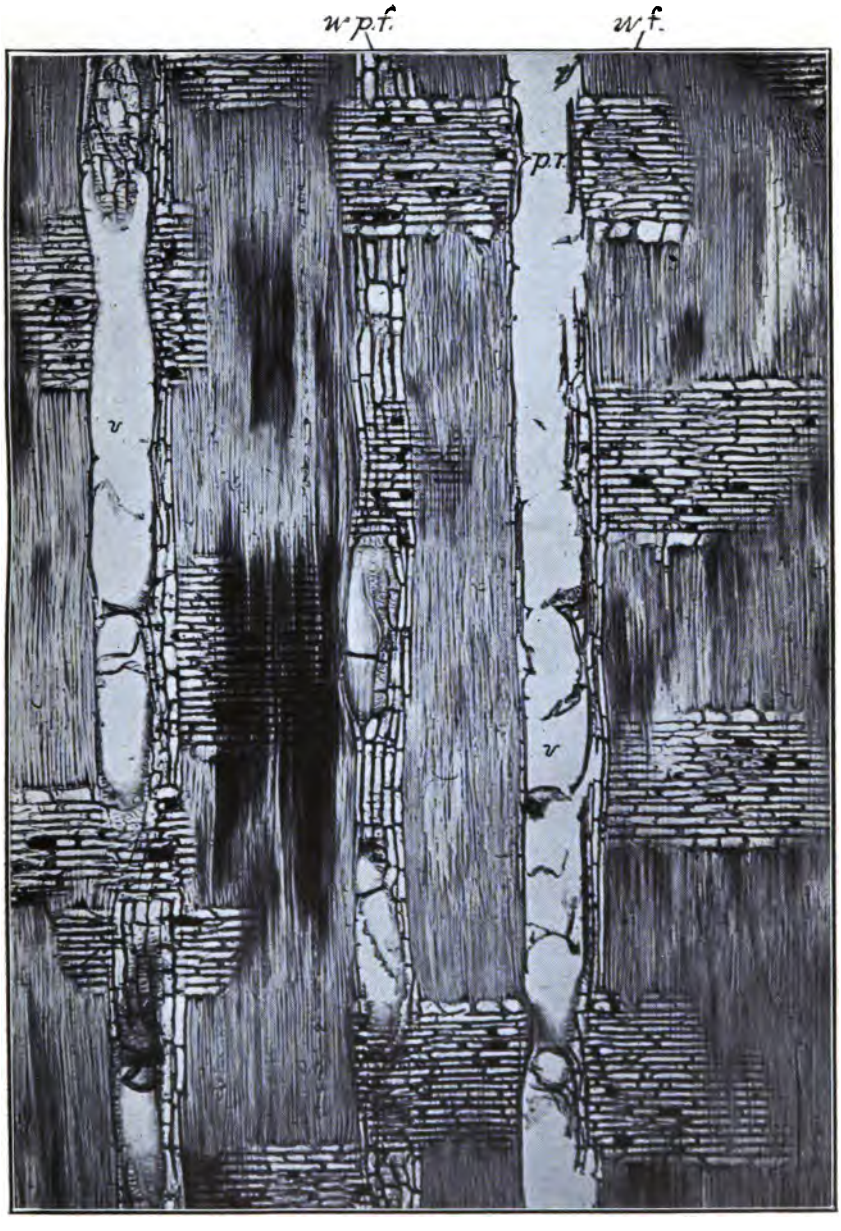
FIG. 1.—A TRAINLOAD OF GREENHEART LOGS FOR EXPORT.

FIG. 2.—LOGGING GREENHEART WITH OXEN.



TRANSVERSE SECTION OF GREENHEART WOOD.

The large black spot in upper left-hand corner represents tylosis. *v*, vessel; *p. r.*, pith ray; *w. p. f.*, wood-parenchyma fiber; *w. f.*, wood fiber. Magnified 50 diameters.



RADIAL SECTION OF GREENHEART WOOD.

v., vessel; *p. r.*, pith ray; *w. p. f.*, wood-parenchyma fiber; *w. f.*, wood fiber. Magnified 50 diameters.

TANGENTIAL SECTION OF GREENHEART WOOD.

v., vessel; *p. r.*, pith ray; *w. f.*, wood fiber. Magnified 50 diameters.

These amounts do not include the vast quantity of greenheart cut each year for charcoal. Approximately 80,000 barrels of this are exported annually. The demand for the wood of young greenheart trees for charcoal became so great that legal restrictions had to be placed upon the cutting of young growth. The market for charcoal is apparently more stable than that for timber, since the amounts of the former exported from year to year show a gradual increase, while the amounts of timber usually fluctuate.

THE TREE.

Greenheart is a large tree, ranging from 60 to 100 feet in height, and from 2 to 4 feet or more in diameter. The trees are without branches for from one-fourth to one-third of their total height. They generally have clean, symmetrical boles for the first 50 or 60 feet, and logs or timbers from 18 to 20 inches square can often be obtained. The bole is free from knots, and unlike that of many of the greenheart's associates is not buttressed. The crown is open and broad with a few heavy branches. The tree is an evergreen, but during the dry season has fewer leaves than during the wet season. Owing to the absence of distinct rings of annual growth, the age at which greenheart reaches maturity is not accurately known. The tree, however, grows very slowly. Specimens known to be 70 years old have reached a diameter of scarcely 8 inches. Hence it is probable that trees of merchantable size, say 20 inches in diameter, are about 250 years old, while others of still larger proportions are relatively older.

GROSS CHARACTERS OF THE WOOD.

When freshly cut the sapwood of greenheart is pale yellow and the heartwood usually of a light grayish-brown, often striped. On exposure the wood turns dark, the outer layers assuming a dark greenish or chestnut color, while the center turns a deep brownish-purple or almost black. The color of both heart and sap wood varies considerably in different trees, and in different parts of the same tree. The heartwood may, in fact, vary from pale yellow to black, and just what the actual color is can not be ascertained until the sapwood has been cut through. The proportion of sapwood is usually excessive, especially in young trees, often amounting to one-fifth and sometimes to one-third of the volume of the trunk. This, however, has little effect upon the lasting qualities of the wood when used above water.

The wood of greenheart is exceedingly hard and heavy (specific gravity from 1.08 to 1.23, or about 75 pounds per cubic foot), tough, strong, elastic, and fine grained. It is said to be the strongest timber in use, with a crushing strength of 12,000 pounds per square inch, 65

per cent greater than that of English oak. In a smooth transverse section (unmagnified) it resembles superficially the wood of palm.

ANATOMICAL CHARACTERS OF THE WOOD.

Like a number of other tropical hardwoods, greenheart shows no annual rings of growth. The ground mass of the wood is composed of small, thick-walled wood fibers arranged in radial rows (transverse section). The vessels, plainly visible to the naked eye on a smooth transverse surface, are distributed either singly or in pairs arranged radially. They are surrounded by several rows of wood-parenchyma fibers which under a compound microscope can be distinguished from wood fibers by their thin walls. The pith rays are very narrow and visible only when magnified.

The *pores* (Pl. III, *v.*) are arranged either singly or in pairs, with an average diameter of 0.13 millimeter, and are fairly constant in size throughout the wood. In outline they are either round or elliptical, with the greatest diameter in the radial direction, and are fairly thick walled. The vessel walls (Pls. III and IV, *v.*) in contact with the pith-ray cells and with wood-parenchyma fibers have numerous bordered pits with transitions to simple pits. These are sometimes large and elliptically elongated, a group often resembling scalariform (ladder-like) markings. The partition wall where the vessel segments join end to end is wholly absorbed (simple perforation), leaving an open passage between the segments. The original partition wall is at right angles to the axis of the vessel, and each vessel segment ends in a small projection which overlaps the next segment above and below. The segments of which the vessels are composed consist of cells approximately five times as long as wide (0.67 millimeter in length).

Wood fibers (Pl. II, *w.f.*) are small in diameter and have such thick walls that the lumina or cell cavities often resemble mere dots in transverse section. The fibers vary in length from 1.14 to 1.51 millimeters, with an average of 1.28 millimeters. The pits are simple, with very narrow canals. These latter are not visible except in transverse section under the high power of the microscope.

Wood-parenchyma fibers (Pl. III, *w.p.f.*) have very thin walls and are only sparingly developed, except where they are grouped around vessels with which they communicate through the round or transversely elongated pits mentioned above. The cells composing the wood-parenchyma fibers show considerable variation in length. The end walls of individual cells are usually at right angles to the long axis of the fiber.

Pith rays (Pl. IV, *p.r.*) are usually from 1 to 2 cells wide and from a few to 30 or occasionally 40 cells high. Individual ray cells

vary in size. Their shape as seen in tangential section is usually round. In radial section they appear as elongated brick-shaped cells, varying greatly in length, with oblique end walls. Both the end and radial walls have small, round, simple pits.

SUBSTITUTES FOR GREENHEART.

The constant drain for more than 100 years upon the most accessible stands of greenheart in British Guiana has stripped the forest of its best material and resulted in the appearance on the market of certain substitutes. The woods of three other species of Nectandra, the white cirouballi or siruaballi (*Nectandra surinamensis* Mes.), yellow cirouaballi (*Nectandra pisi* Miq.), sometimes called "black cedar," and the keritee or kretti (the exact species of which is not known), which grow with greenheart throughout its entire range, are occasionally cut and sold with the genuine. While they closely resemble it, they are inferior in durability. The white cirouaballi, however, is an important tree, and its wood is likely to be substituted more extensively as the supply of true greenheart diminishes. The woods of the two other species are much lighter than true greenheart, the yellow cirouaballi weighing 52, and the kretti 32 pounds per cubic foot, as against 75 pounds for the genuine, and their substitution should be easy to detect. These two species work well, and are used largely for planking. The kretti wood strongly resembles cigar-box cedar (*Cedrela odorata* Linn.) in aroma, grain, texture, and ease of working, but is very much paler in color.

The woods of two species of leguminous trees of West Africa have been introduced into English markets as substitutes for greenheart, under the name of African greenheart. One is from the recently described tree Piptadenia (called "okan" by the natives), which attains large size, especially in the Gold Coast region. This wood is valued at from 30 to 36 cents per cubic foot. The other species is an undescribed tree from Nigeria, which yields a wood known locally as essago, selling for from 36 to 42 cents per cubic foot. Both of these species are inferior to true greenheart, and it is not likely that they will take its place to any great extent.

An East African tree called greenheart is *Walburgia ugandensis* Sprague, better known to the natives of East Africa as "masuka" or "m'ziga." Its heartwood is green in color, beautifully figured, and sweet scented. The supply, however, is rather limited, and it is not likely to enter the markets of Europe or America. None of the African woods possesses the lasting qualities of the true greenheart of British Guiana.

Several comparatively unimportant trees of the West Indies are called greenheart, but they are not sufficiently valuable to enter into competition with true greenheart. One of these is the snakewood,

ironwood, or abelluello (*Colubrina ferruginosa* Brongn.), often called West Indian greenheart. The wood is strong and durable, but is much inferior to the true greenheart. The tree from which this comes is comparatively small, seldom over 75 feet high, and 2 feet in diameter, even in Martinique, where it attains its best development. Owing to its small size, the substitution of this wood for true greenheart must necessarily be very limited. Another species of this genus, *Colubrina reclinata* Brongn., a relatively low tree, seldom over 60 feet high, found in the mountains of Cuba, yields a strong and durable wood sometimes referred to as greenheart. The greenheart of Jamaica (also called cogwood or cerillo) is the *Ceanothus chloroxylon* Nees. It is a small tree and does not enter into competition with the genuine greenheart. Still another tree from Jamaica sometimes called greenheart is *Zizyphus chloroxylon* Oliver. It is of good size throughout the interior hills, though not plentiful. The wood is dark, close grained, and weighs about 70 pounds per cubic foot.

Greenheart is the name applied also to a Jamaican tree, *Sloanea jamaicensis* Hook., which grows from 70 to 100 feet in height, with a trunk about 2 feet in diameter. It is confined largely to the interior of the island, where it attains its largest sizes in the limestone soil. The wood is very hard, heavy, fine grained, dark colored, and is suitable for a good many purposes. It is said to be very durable in contact with the soil.

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FOREST SERVICE—CIRCULAR 212.

HENRY S. GRAVES, Forester.

CIRCASSIAN WALNUT.

BY

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WASHINGTON:
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1913.

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CIRCASSIAN WALNUT.

COMMON NAMES.

Circassian walnut (*Juglans regia* Linn.) yields one of the best known and most expensive cabinet woods on the American and European markets. Botanically, Circassian walnut is the same as the so-called English walnut, the latter name being used almost exclusively by those who grow the tree for its nuts; while the former is the one generally applied to it by manufacturers and other consumers of the wood. Of all the common names given it, English walnut is the least appropriate, because the tree is not a native of England, but was brought there long ago from Asia and cultivated. Obviously, the most appropriate name for the tree is Circassian[1] walnut, since this indicates at once its true origin and natural range. Other common names applied to it are royal walnut, Italian walnut, European walnut, French walnut, Persian walnut, Austrian walnut, Turkish walnut, and Russian walnut. In Italy the tree is called ancona auvergne; in Persia, jaoz, charmagz, and akrot; in Greece, carua, caryon, Persicon, and basilikon (kingly tree); in France, noyer; in Germany, englische Wallnuss and gemeine (common) Wallnuss; in Spain and Cuba, nogal; in South America nogal, nogal America, and nogal comun.

USES.

Probably no other wood has served so many purposes as Circassian walnut. Long before the discovery of America it was the most popular of all woods for furniture and interior finish, while throughout southern Europe the wood is still used locally for all grades of furniture. Its present high cost, however, prohibits its use in this country for any but the very finest furniture and cabinet work. When more abundant, its use abroad also included coach making, turnery, toys, press screws, joinery, carved work, and wooden shoes. During the wars of the eighteenth century Circassian walnut was used so extensively for gunstocks that even at that early date the supply was seriously decreased.

The wood of old trees is especially valuable on account of its dark color and beautiful veining, strength, lightness, and elasticity.

[1] This term is derived from Circassia, a region of western Caucasus, now included in the Russian Government of Kuban and Chernomorsk, lying between the Black Sea on the southwest and the river Kuban on the north.

When particularly well marked it is one of the most attractive and valuable of veneer woods, particularly for furniture. The best grades often bring a higher price than mahogany, especially in the United States.

NATIVE AND CULTIVATED RANGE.

Adapted to a wide range of soils and climatic conditions, Circassian walnut is one of the most widely distributed of commercial timber trees. It is native to the eastern slopes of the Caucasus, and extends eastward along the valleys and slopes of the Hindoo Koosh to the southern foothills of the Himalaya Mountains, where it is said to form large, pure forests. From there it extends southward to northern India, and to the mountains of upper Burma. Some authorities claim that it stretches across the continent to Japan.

Sir Dietrich Brandis describes trees from the region northwest of the Himalayas as being 28 feet in circumference and from 100 to 120 feet in height. It is probable that the species reaches its best development in the Caucasus Mountains. In the Sikkim Himalaya, according to Dr. Joseph Hooker, an English botanist, Circassian walnut inhabits mountain slopes between elevations of 4,000 and 5,000 feet, while in northern India it is found at elevations of from 3,500 to 11,000 feet, being most abundant in Kashmir. It grows also to some extent in the arid valleys.

In northeastern India (Darjeeling) Circassian walnut is planted extensively for its fruit. It has been widely planted in Europe, having been grown successfully as far north as Warsaw in Russia, and as far south as Italy and the Mediterranean islands. According to Pliny it was introduced into Italy from Persia. This must have happened at an early date, since it is mentioned as existing in Italy by Varro, who was born 116 B. C. There is no authentic record as to when Circassian walnut was brought into the United States. Here it has been planted from the Atlantic to the Pacific, the greatest attention having been given to it on the Pacific coast, where it is grown for its nuts. Since wherever it is grown in the United States it is for this purpose, the wood produced is of little importance.

SOURCES OF SUPPLY.

No other timber tree has been exploited more than Circassian walnut, and the demand for it has always been greater than the available supply. Much of the Circassian walnut now used in various parts of the world comes from the shores of the Black Sea, and from other regions as far as Persia. Large shipments come from India to England, whence some is shipped to the United States. The greatest outlet of southern Russia is probably from Odessa, and the bulk of the timber is shipped direct to the United States.

None of the wood grown in western Europe is shipped to this country. That grown in England is not equal in quality to the wood from the Caucasus, though it is much sought after for furniture, and particularly for gunstocks. In fact, the demand for these purposes in western Europe is so great that the domestic supply invariably fails to meet it, and at times there has been a great dearth of the wood there. Realizing the importance of a home supply, France passed an act in 1720 prohibiting the exportation of Circassian walnut. The shortage of supply in Europe has been due chiefly to the enormous demand for gunstocks in times of war. The wood of approximately 12,000 trees was required early in the nineteenth century for this purpose alone. In consequence, large numbers of plantations were established throughout England, France, and Germany. Some of these were very extensive; one founded in 1818 near Boulogne, France, contained about 30,000 trees.

Widespread consumption of Circassian walnut for gunstocks and furniture continued in Europe until its cost became very high and importation began from the Orient. Liverpool and London were then, and still are, the chief ports of entry from which Circassian walnut is reshipped to Continental Europe and to some extent to the United States. During the last 20 years, however, American dealers have imported directly from the country where the wood is cut, and only small shipments come to this country via London and Liverpool.

Profit from growing Circassian walnut in Europe for timber is much less than it once was, both because large quantities (about 20,000,000 feet) of our native black walnut are annually shipped there, and because the wood is now coming from the East.

LOGGING AND TRANSPORTATION TO MARKET.

Circassian walnut grows for the most part either in very open stands or scatteringly in forests of other species. Trees grown in dense stands do not produce the most highly prized qualities of timber. Those which yield the best wood grow in the open, often in unfavorable situations, and as a rule have small, short, crooked trunks. Such trees are so scattered and so few in number in any one locality that lumbering is made very expensive. Extensive logging has, in fact, never been carried on anywhere in the tree's range.

The wood is so heavy when green that it sinks in water and can not be floated. Logs must be hauled from the forest to the shipping point over poor roads and by crude equipment. Transportation is becoming more and more difficult and expensive, especially since logs have to be obtained at points far from water transportation, the timber on more accessible areas having been exhausted. Cir-

cassian walnut logs at shipping points are now bought by the pound or ton, never by board foot measure. The average price paid for logs at shipping ports is from $80 to $100 per ton, or a little more than 4 cents a pound. This high cost is due partly to the great expense of delivering logs overland, partly to the fact that most of the trees produce small, poorly formed, or defective sawlogs, and partly to the fact that a great deal of territory has to be gone over to obtain a shipload of logs. Were it not for the exceptionally high value of the wood no one could afford to lumber walnut forests.

Unlike most other saw timber the straighter and better-formed trees do not yield the most highly prized quality of lumber. It is usually the crooked, irregular logs that contain the most highly figured wood, the logs affording such material being valued according to the amount they contain. Single trees containing choice burls, crotches, or fine bird's-eye effects have sold for over $3,000. Timber of this exceptional quailty is now scarce, while all grades in fact are becoming more difficult to obtain. Even a considerable advance in price would not in all probability greatly increase the present imports. All useful parts of the trees are now saved, even to the stumps and other pieces formerly left to rot.

WASTE IN PREPARING LOGS FOR SHIPMENT.

Russia, which is at present the chief source of the Circassian walnut which comes to American markets, has an export duty of $20 per ton. In addition to this there are port and town charges, which help to swell the cost of the wood. Logs are all sold from the forest with the bark and sapwood on. Since only the heart wood is used, these are hewn from the logs before final shipment in order to reduce the cost of transportation. After the logs are thus prepared for shipment they are carefully inspected and weighed by customs officials before being loaded on ships. The hewing of the logs is expensive, in that it is a crude way to remove useless parts, and wasteful, because the sapwood removed brings the shipper nothing, although he has been obliged to pay for it. The average thickness of the sapwood taken off is from 4 to 6 inches. Unsound or defective parts of the logs are also removed, since the importer must pay freight alike on sound and unsound timber. However, when logs contain finely figured but slightly unsound pieces, which might be suitable for veneer, the defects are usually allowed to remain.

CONSUMPTION OF CIRCASSIAN WALNUT IN THE UNITED STATES.

The exact amount of Circassian walnut shipped into this country can not be ascertained because it is included under the general head of cabinet woods. However, the United States is believed to be the greatest consumer of Circassian walnut, especially of the highly

figured grades. During 1911 the consumption in 14 States was 852,807 board feet,[1] which may safely be assumed as only about one-third of our total consumption. Table 1 shows the amounts used in the 14 States referred to.

TABLE 1.—*Circassian walnut consumed in 1911 in States for which reliable data were obtainable.*

State.	Board feet.	State.	Board feet.
Missouri	2,400	New Hampshire	1,200
Michigan	252,557	Louisiana	1,000
Oregon	300	Kentucky	20,000
Maryland	506,500	Wisconsin	5,200
North Carolina	3,000	Vermont	1,000
Illinois	40,500	Connecticut	3,800
Virginia	350		
Massachusetts	15,000	Total	852,807

GROSS CHARACTERS OF THE WOOD.

Circassian walnut weighs about 45 pounds per cubic foot, is hard, compact, easy to work and split, moderately tough, and durable in contact with the soil. It shrinks very little in seasoning and does not crack or warp. The sapwood is a pale fawn color or almost white. The heartwood is dark chocolate brown, often shading from light brown to black. Burled and other highly figured forms of the wood take a beautiful finish. Radial (edge-grain) and tangential (bastard) cut boards are always lighter in tone than transverse sections. In light-colored sticks the annual rings of growth are clearly but not strikingly defined, but in dark specimens are very indistinct. The pores are irregularly scattered. (Plate I.)

The wood of trees grown in poor upland and hilly soils has a beautiful fine grain and texture, while the wood grown in rich lowland soils is much coarser and less beautifully marked. The best qualities of timber are obtained from vigorous sound trees over 100 years old, which rarely have a clear length of more than 12 feet. The most beautifully veined wood is in the roots and burls, the latter being particularly common on trees near the Black Sea. The grain in such growths is so interwoven and twisted as to produce the most curious and irregular figures, giving the wood an unequal value for veneer. (Plate II.)

MINUTE CHARACTERS OF THE WOOD.

Since the increasing scarcity of Circassian walnut may result in attempts to substitute for it woods difficult to distinguish by superficial characters, the chief structural characters of this wood (vessels, tracheids, wood fibers, wood-parenchyma fibers, and pith-rays) are illustrated and briefly described. Most of them can be seen with an ordinary pocket lens.

[1] Compiled by Branch of Products, Forest Service.

Vessels or pores (transverse section) (Plate III, *v.*) are uniformly distributed. In early wood or inner part of each annual ring (Plate III, *e. w.*) they are usually oval in outline, with an average tangential diameter of 0.16 millimeter, while in late wood (Plate III, *l. w.*) they are round and have an average diameter of 0.12 millimeter. The size of the pores diminishes gradually from early to late wood, so that the inner and outer portions of annual rings of growth are alike in general appearance, and similar to those in gums and cottonwoods. In very broad annual rings the vessels become smaller toward the outside, thus making the difference between early and late wood more conspicuous than in narrower ringed wood. The pores are arranged singly, or occasionally in pairs, separated by a partition wall on their tangential sides. It is rare that pores are grouped in threes or fours, and then only in very narrow rings of growth, where they may be somewhat radially arranged.

The walls of vessels are much thinner than those of the surrounding wood fibers, and thinner also than those of vessels of our native walnuts. In longitudinal section (Plate IV, *v.*) the vessel segments are from one to three times as long as wide, and usually have oblique terminal partition walls (slanting ends), which always face the pith-rays and are always wholly absorbed, leaving a large opening between the abutting segments, known as a simple perforation. The oblique line, Plate IV, *c. w.*, shows a portion of the unabsorbed cross-wall near its outer edge where the two segments meet. The vessel walls are densely and uniformly marked with bordered pits (Plate IV, *b. p*). The upper and lower surfaces of the vessel segments (Plate IV, *v.*) have been cut away, leaving only a small portion showing the pits, *b. p.*

Wood fibers[1] (transverse section) (Plate III, *w. f.*) are arranged more or less irregularly. They have thin walls, comparatively large cell cavities, and in outline are usually round, except in the case of fibers which border vessels or occur in the last few rows in the late wood (Plate III, *l. w.*), where they are invariably flattened radially or tangentially. They are often compressed tangentially also where they border pith-rays. Wood fibers (longitudinal section) (Plates IV and V, *w. f.*), which are long pointed (acuminate) or occasionally[2] forked or notched at both ends, are from about 1.0 to 1.8, with an average of 1.4, millimeters in length and 0.02 millimeter in diameter. The pits in the walls of wood fibers are few, small, simple, and chiefly on the radial walls.

Wood-parenchyma fibers (transverse section) (Plate III, *w. p. f.*), readily seen with a hand lens, form narrow, tangential, slightly colored lines, which are often somewhat wavy, especially near the

[1] In the late wood these elements occur in distinct radial rows, which can, however, be seen only under the high power of the microscope.

[2] Only in gnarled and slowly-grown woods.

early wood (Plate III, *e. w.*). They are seldom more than one row of cells wide. In a magnified section (Plate V, *w. p. f.*), the character and composition of wood-parenchyma fibers are clearly shown. Each fiber is composed of from 5 to 10 small oblong cells [1] arranged in a perpendicular row, and closely packed between the wood fibers. The upper and lower cells of all wood-parenchyma fibers taper to a point. Wood-parenchyma fibers are almost one-third shorter than the average wood fiber. Crystals of calcium oxalate and carbonate, so numerous in the wood-parenchyma fibers of black walnut (*Juglans nigra*), are seldom found in Circassian walnut.

Pith rays (Plate III, *p. r.*), which are most conspicuous in a smooth transverse section, appear as numerous, fine radial lines composed of short parenchymatous cells arranged in rows from 1 to 5, seldom more than 4, cells in width. As a rule the rays are straight, though occasionally they bend slightly around large pores or vessels in the early wood of wide annual rings of growth. In a tangential section they are cut off at right angles to their axes (Plate IV, *p. r.*), exhibiting more clearly their form and character. Some rays are spindle-shaped and composed of numerous irregular cells, while others are only a single cell wide and from 1 to 10 cells high. In a radial section the pith-rays are cut longitudinally. The pitting of the cells composing the rays is shown very distinctly under the high power of a compound microscope. The individual cells of a ray differ very little from those which make up wood-parenchyma fibers. Pith-rays (tangential section) in the wood of Circassian walnut are spindle-shaped, and from 1 to 5 cells wide, while in butternut, a closely related species sometimes substituted for the latter, the pith-rays are spatulate and usually from 1 to 3 cells wide.

SUBSTITUTES FOR CIRCASSIAN WALNUT.

Although it is usually easy for expert buyers to recognize true Circassian walnut in the logs, it is often difficult to distinguish the wood from some of its substitutes when these have been skillfully stained and finished. There are many good African, Asian, and South American woods which are similar in structural qualities to Circassian walnut, though none possesses the magnificent figure, delicate tones, and velvety texture of the walnut. Chief among the woods which resemble Circassian walnut in general appearance is the so-called satin walnut, tassel wood, or red gum (*Liquidambar styraciflua* Linn.) of the United States, the wood of which has been sold as Circassian walnut both for furniture and for interior finish. The wood from butt logs of red gum is often handsomely veined and mottled, and is strikingly similar in general appearance to Circassian

[1] When magnified 100 diameters cells show numerous, small, round openings called simple pits, which connect the cell cavities of each element with those of adjoining elements.

walnut. The much finer grain and more numerous and much smaller pores of red gum, however, can be depended upon to distinguish it from the latter. Our native cotton gum (*Nyssa aquatica* Linn.) is another wood occasionally sold as Circassian walnut. It has a similar texture,[1] but the lack of pronounced figure readily distinguishes it.

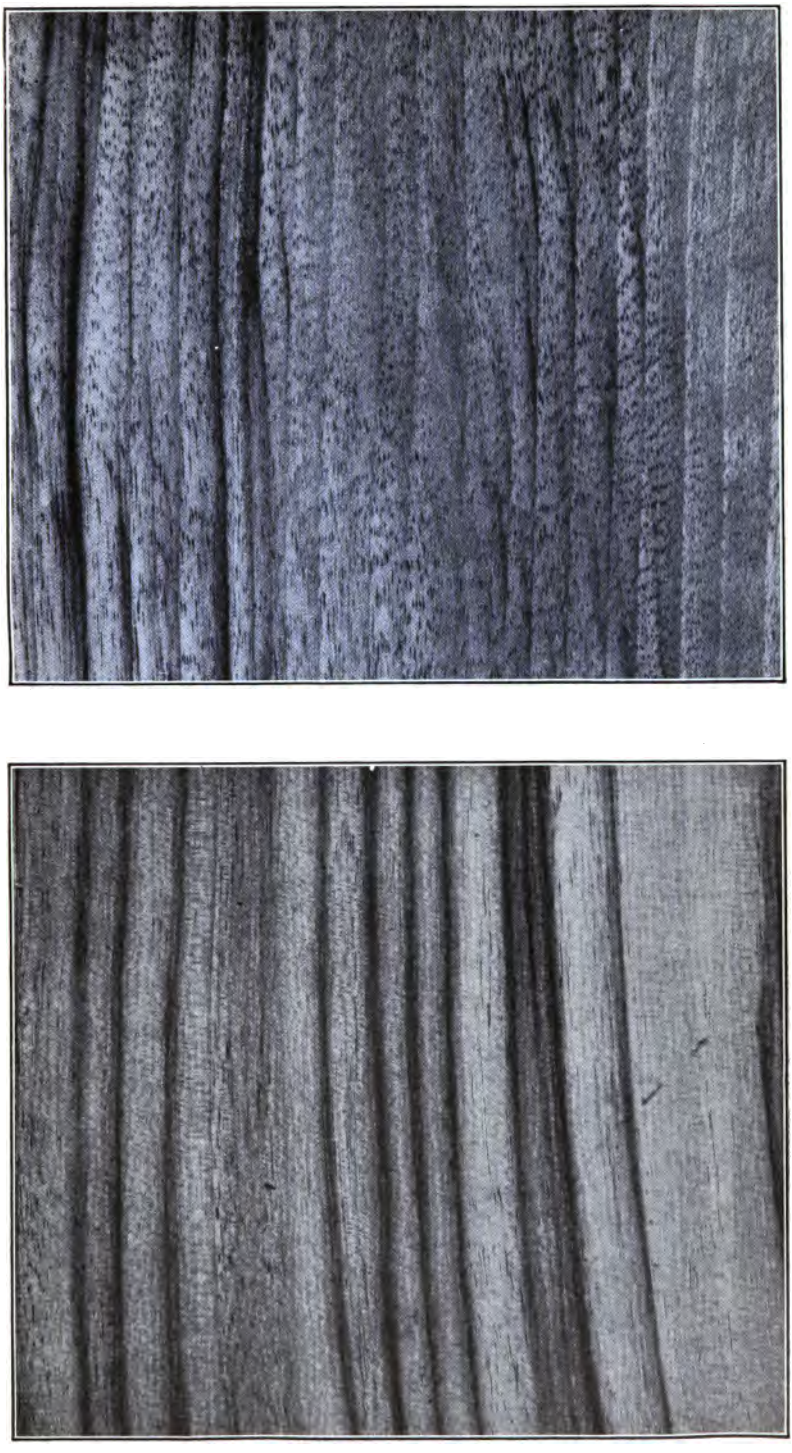
Among the true walnuts and related woods which may appear as substitutes are Caucasian walnut (*Pterocarya caucasica* C. A. Mey. = *P. fraxinifolia* Spach.), Japanese pterocarya (sawa-gurumi) (*Pterocarya rhoifolia* S. et Z.), butternut (*Juglans cinerea* Linn.), Jamaican, or West Indian, walnut (*Juglans insularis* Griseb.), and nogal (*Juglans australis* Griseb.).

Owing to the similarity of names, Caucasian walnut is sometimes confused with Circassian walnut, but the wood of the former lacks figure, is harder, denser, and much inferior from the cabinetmaker's standpoint. The entire absence of figure in the Caucasian walnut at once serves to distinguish it from the Circassian walnut. The Japanese pterocarya is an important timber tree, and although its wood somewhat resembles Circassian walnut in its minute structural characteristics, its gross appearance is very different, and its substitution should be easily detected. This Japanese wood is white, soft, very light, and straight grained, with rows of open pores marking the annual rings of growth. A writer on Japanese woods states that it might be mistaken at first glance for white pine.

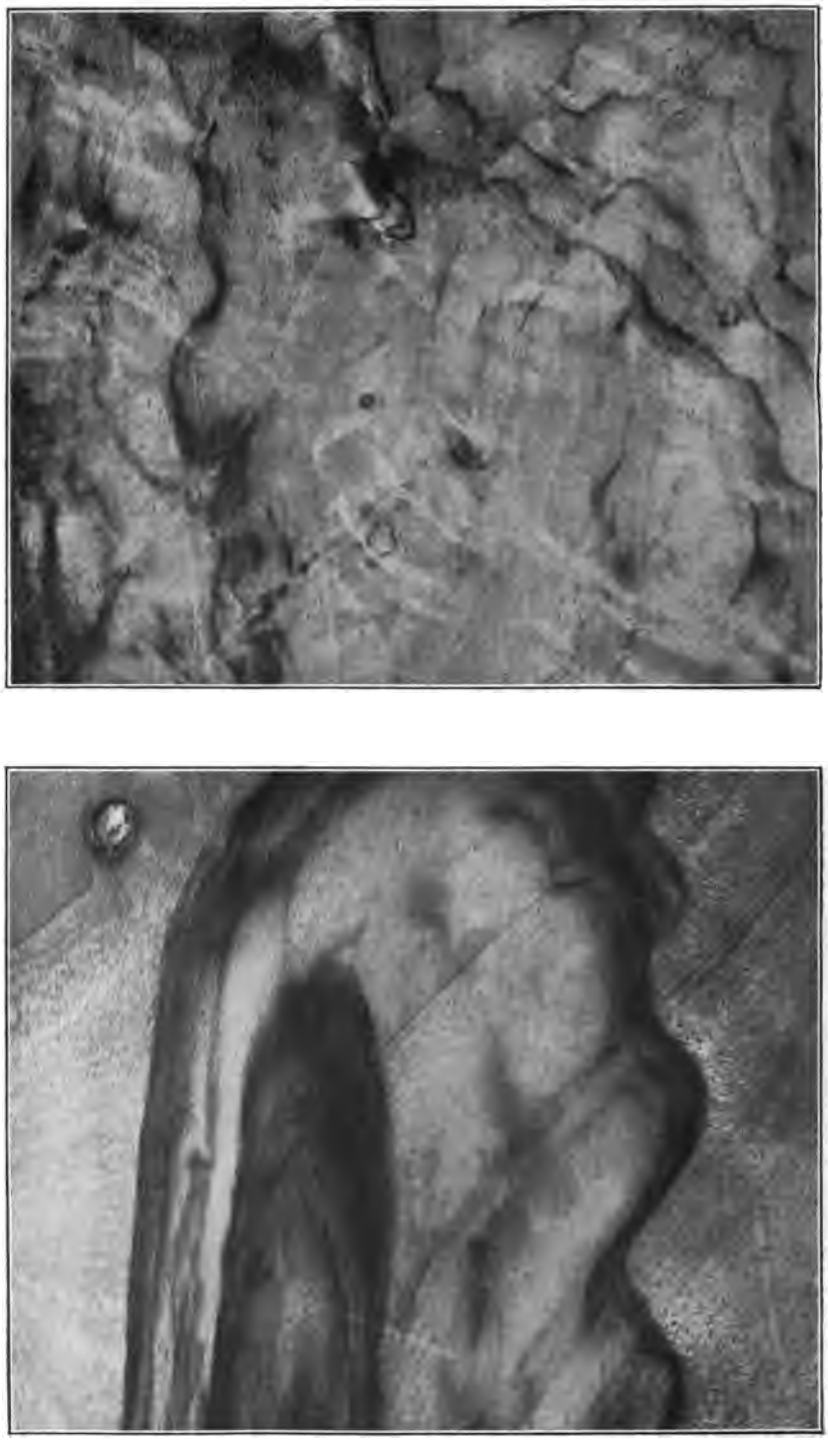
The butternut is the only one of our native woods that could be substituted to any considerable extent for Circassian walnut. Some of its grades are remarkably similar in general appearance to the less highly figured ones of the latter. The light and dark brown, and black veining of the Oriental wood, however, readily distinguishes it from the solid brown shades of the butternut. Three closely related Asiatic walnuts[2] have wood similar to that of the Circassian walnut, but are nowhere sufficiently abundant to play a large part in possible substitutions. The little known West Indian walnut and the nogal, or South American walnut, are excellent woods, but only limited supplies are available, and hence are likely to find their chief use in local cabinetwork. Nogal is especially desirable as a cabinet wood because of the ease with which it can be worked and the beautiful finish it takes. Both of these woods are coarser grained than Circassian walnut, and when well finished resemble black walnut.

[1] See Forest Service Bulletin 103, "Distinguishing Characteristics of North American Gum Woods."

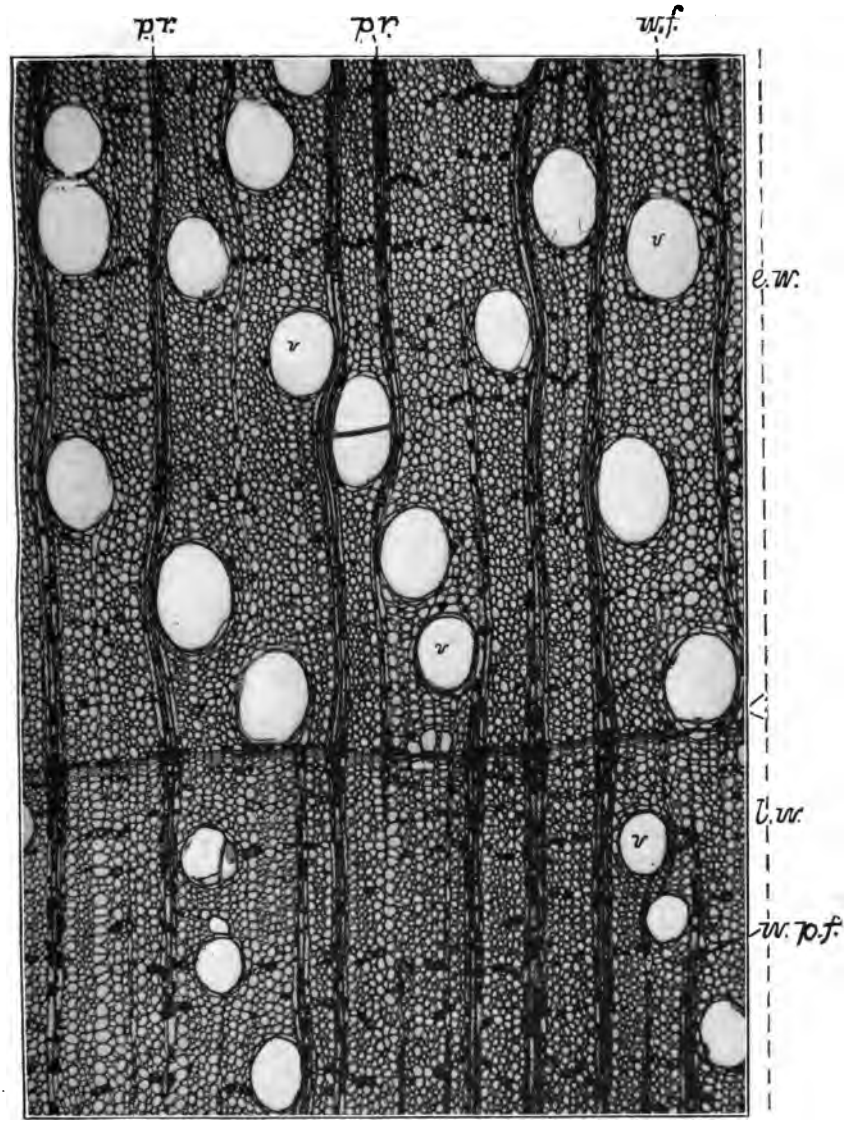
[2] *Juglans sieboldiana* Maxim., *J. mandshurica* Maxim., and *J. cordiformis* Maxim.



FIGS. 1 AND 2.—VENEER FROM STRAIGHT-GRAINED LOGS.

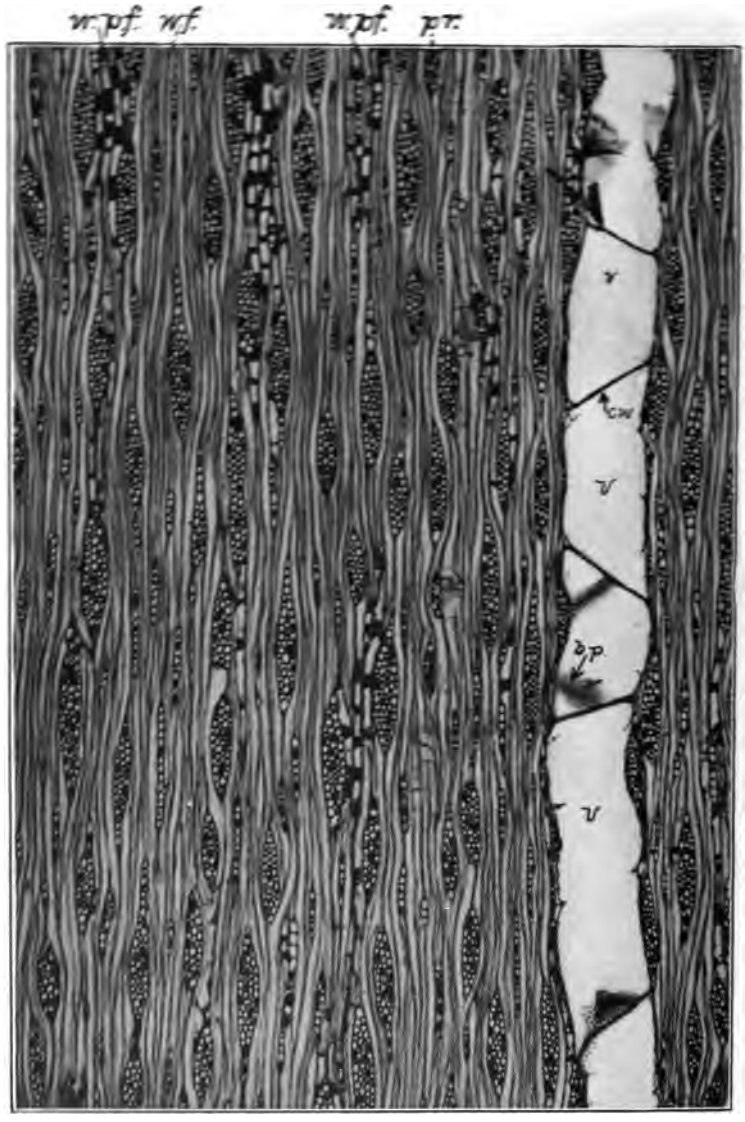


FIGS. 1 AND 2.—VENEER FROM CROOKED AND IRREGULAR LOGS.



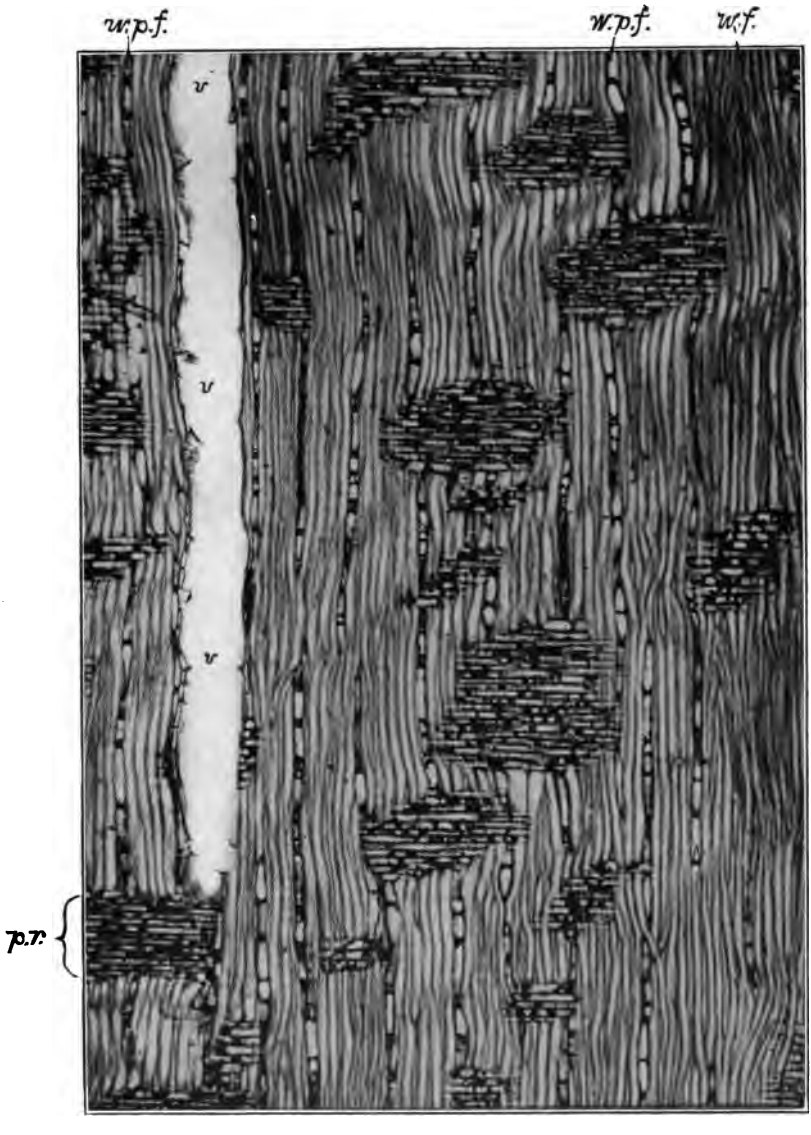
TRANSVERSE SECTION OF THE WOOD OF CIRCASSIAN WALNUT (JUGLANS REGIA).

v., vessels; *p. r.*, pith rays; *w. f.*, wood fibers; *w. p. f.*, wood-parenchyma fibers; *e. w.*, early wood; *l. w.*, late wood. Magnified 50 diameters.



TANGENTIAL SECTION OF THE WOOD OF CIRCASSIAN WALNUT (JUGLANS REGIA).

v, vessel; *p. r.*, pith ray; *w. f.*, wood fibers; *w. p. f.*, wood-parenchyma fibers; *c. w.*, cross wall; *b. p.*, bordered pits. Magnified 50 diameters.



RADIAL SECTION OF THE WOOD OF CIRCASSIAN WALNUT (JUGLANS REGIA).

v., vessel; *p. r.*, pith ray; *w. f.*, wood fibers; *w. p. f.*, wood-parenchyma fibers. Magnified 50 diameters.

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HENRY S. GRAVES, Forester.

FOREST PRODUCTS LABORATORY SERIES.

MECHANICAL PROPERTIES OF WOODS GROWN IN THE UNITED STATES.

PRELIMINARY SUMMARY OF TESTS ON SMALL, CLEAR, GREEN SPECIMENS OF FORTY-NINE SPECIES OF WOOD.

WASHINGTON
GOVERNMENT PRINTING OFFICE
1913

FOREST SERVICE.

HENRY S. GRAVES, *Forester.*
ALBERT F. POTTER, *Associate Forester.*
HERBERT A. SMITH, *Editor.*

BRANCH OF PRODUCTS.

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TIMBER TESTS.

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[illegible]	[illegible]	[illegible]	.....	.....	.....	1,200	1,215	.....	.....	.....	.....
4,760	1,681	1,224	.....	.....	.....	1,235	1,620	.....	.....	.....	.....
4,820	1,911	1,130	.....	.....	.....	1,312	1,405	.....	.....	.....	.....
4,820	1,980	1,114	.....	.....	.....	1,334	1,457	.....	.....	.....	.....
5,060	1,869	1,158	.....	.....	.....	1,206	1,318	.....	.....	.....	.....
4,360	1,478	1,080	.....	.....	.....	1,337	1,505	.....	.....	.....	.....
4,370	1,029	.....	.....	.....	.....	.....	1,245	.....	.....	.....	.....
4,600	1,943	972	.....	.....	.....	1,230	1,297	.....	.....	.....	.....
4,660	1,926	1,088	.....	.....	.....	1,390	1,490	.....	.....	.....	.....
4,970	1,536	1,684	1,862	1,860	1,832	1,885	2,096	552	610	1,133	1,445
3,680	.....	606	766	621	626	1,130	1,330	297	330	.....	.....
3,670	1,463	653	992	918	901	1,193	1,455	376	513	610	864
4,000	.....	870	965	815	815	1,340	1,530	357	451	.....	.....
3,330	1,062	1,148	1,139	1,068	1,081	1,196	1,402	354	487	714	924
3,440	1,335	844	1,139	1,044	1,039	1,215	1,226	367	446	659	880
3,210	1,295	807	1,107	1,020	1,002	1,132	1,195	380	470	639	874
3,460	1,924	682	924	884	901	1,047	1,059	365	410	683	787
4,360	1,489	943	1,205	1,217	1,099	1,198	1,394	428	536	757	909
4,840	.....	1,355	.....	.....	.....	.....	1,414	.....	.....	.....	.....
3,520	946	829	1,113	1,030	943	1,096	1,292	382	457	622	749
3,530	1,308	727	1,087	1,049	1,047	1,187	1,425	342	506	632	997
3,490	1,181	1,004	1,183	1,163	1,147	1,138	1,368	371	474	624	986
3,700	1,465	912	1,093	1,083	1,031	1,162	1,196	379	470	728	929
3,080	.....	802	847	800	790	1,270	1,320	337	365	.....	.....
5,810	1,331	2,260	1,838	2,312	1,762	.....	.....	.....	.....	.....	.....
2,790	1,073	433	664	560	599	900	1,102	265	425	540	781
3,550	1,280	451	814	666	733	978	1,084	277	380	472	796
1,990	754	288	321	225	228	617	614	148	139	241	235
3,030	868	518	.....	.....	.....	613	662	.....	.....	.....	.....
3,960	1,738	548	460	355	354	836	800	167	154	242	251
2,060	882	307	284	203	235	573	654	130	133	.....	.....
3,640	1,579	334	.....	.....	.....	517	639	.....	.....	.....	.....
2,920	1,440	427	415	399	416	853	858	139	127	.....	.....
2,800	1,332	445	381	322	334	742	723	145	187	213	304
2,750	1,054	420	463	354	334	790	813	168	151	271	323
2,530	1,219	364	288	307	316	672	747	142	140	.....	.....
2,400	991	332	316	318	319	709	719	253	200	.....	.....
4,280	1,890	491	574	502	521	1,060	953	187	180	240	298
3,080	1,646	358	355	345	340	812	741	161	154	179	205
3,570	.....	400	.....	.....	.....	746	670	.....	.....	.....	.....
2,600	1,029	353	334	307	342	702	714	168	189	239	304
2,220	1,046	342	310	311	318	644	680	152	179	281	321
2,420	1,271	326	316	306	323	686	706	162	187	230	252
2,600	1,174	410	315	330	332	694	717	152	154	.....	.....
2,720	1,318	314	304	294	299	649	639	144	160	225	285
3,820	1,175	539	.....	.....	.....	.....	.....	.....	.....	.....	.....
4,160	1,272	618	.....	.....	.....	.....	.....	.....	.....	.....	.....
2,170	1,021	302	272	253	274	607	624	110	135	.....	.....
1,800	971	279	231	216	226	538	600	129	143	.....	.....
2,920	.....	322	.....	.....	.....	754	783	.....	.....	.....	.....
1,940	.....	262	.....	.....	.....	645	615	.....	.....	.....	.....
3,480	1,596	480	401	380	370	883	843	167	159	236	274

....	15.3	6.3	9.5	6,820	12,360	1,553	1.71	27.7	88.7	.....	.....	.....	....
....	16.9	6.8	10.9	6,140	11,450	1,605	1.34	34.9	87.9	.....	.....	.....	....
....	21.2	8.5	13.8	5,860	11,810	1,769	1.12	30.6	86.7	.....	.....	.....	....
....	16.0	6.5	10.2	6,220	11,330	1,638	1.34	16.7	64.2	.....	.....	.....	....
....	18.4	7.9	11.4	5,430	10,990	1,346	1.27	34.1	86.4	.....	.....	.....	....
....	.....	.....	.....	5,900	10,170	1,392	1.61	11.9	75.3	.....	.....	.....	....
....	15.5	6.5	9.7	6,120	11,000	1,752	1.22	18.3	72.3	.....	.....	.....	....
....	.....	.....	.....	5,980	10,740	1,563	1.29	18.8	52.9	.....	.....	.....	....
759	8.6	.....	.....	6,020	12,360	1,732	1.28	17.3	64.4	13,460	2,114	4.76	50
....	.....	.....	.....	4,450	8,310	1,445	.78	9.8	17.1	11,670	1,411	5.45	50
643	14.3	4.9	9.1	4,630	8,860	1,462	.88	12.7	32.0	11,680	1,680	4.55	50
....	.....	.....	.....	4,620	8,820	1,437	.85	9.6	16.2	13,780	1,581	6.75	50
732	16.0	5.7	10.6	4,720	7,380	913	1.39	9.1	17.4	11,260	1,596	4.41	50
662	14.5	4.2	8.3	3,890	8,100	1,248	.70	12.7	40.5	10,800	1,553	4.21	50
660	13.1	3.7	8.3	3,490	7,780	1,268	.60	11.4	26.0	10,580	1,506	4.16	50
....	.....	.....	.....	4,370	8,120	1,474	.75	9.8	26.4	10,250	1,803	3.30	50
792	17.7	5.5	10.6	5,380	9,860	1,593	1.05	14.5	37.6	13,280	2,048	4.79	50
....	.....	.....	.....	6,580	10,710	1,678	1.49	.....	.....	.....	.....	.....	....
704	15.8	6.2	8.3	4,320	8,090	1,137	.95	12.1	36.7	9,860	1,414	3.84	50
696	14.3	4.9	9.0	4,780	8,640	1,311	1.18	13.3	35.5	10,980	1,567	4.31	50
708	16.0	4.8	9.2	4,410	7,760	1,194	.94	8.9	19.3	11,750	1,481	5.23	50
669	14.2	4.5	9.7	5,060	8,570	1,219	1.20	11.7	30.7	10,840	1,479	4.44	50
....	.....	.....	.....	3,720	7,650	1,121	.71	13.2	36.3	11,590	1,177	6.44	50
838	8.9	.....	.....	7,760	13,660	1,329	2.53	37.9	101.7	15,520	1,498	8.92	100
526	13.5	5.0	7.3	2,820	6,300	964	.51	7.1	13.6	8,180	1,165	3.22	50
545	12.4	4.4	7.9	4,300	7,380	1,045	1.00	7.8	20.9	7,650	1,310	2.49	50
315	7.0	2.1	4.9	2,600	4,250	643	.60	5.7	9.5	5,290	778	2.04	50
....	.....	.....	.....	3,950	6,040	754	.....	.....	.....	.....	.....	.....	....
513	11.5	3.8	6.0	4,430	7,110	1,378	.96	5.1	15.4	8,290	1,431	2.71	50
321	9.0	2.5	7.1	2,366	4,450	861	.66	4.4	7.4	5,280	982	1.59	50
....	.....	.....	.....	4,060	6,570	1,323	.....	.....	.....	.....	.....	.....	....
458	10.9	3.7	6.6	3,570	6,340	1,242	.59	6.6	13.6	8,870	1,579	2.79	50
437	10.2	3.4	7.0	3,880	5,970	1,131	.77	5.2	14.9	7,230	1,326	2.21	50
394	9.2	2.3	5.0	3,410	5,770	917	.73	6.6	12.9	6,330	1,025	2.19	50
415	11.3	4.2	7.1	3,080	5,130	1,015	.54	5.1	7.4	6,870	1,142	2.31	50
407	10.1	3.6	5.9	2,750	5,170	972	.45	5.3	11.9	6,410	1,108	2.07	50
599	12.8	6.0	7.6	5,090	8,630	1,662	.88	8.1	34.8	9,680	1,739	3.02	50
507	11.5	4.5	7.2	3,740	6,430	1,384	.59	5.8	28.0	7,480	1,438	2.18	50
....	.....	.....	.....	4,360	7,710	1,395	.....	.....	.....	.....	.....	.....	....
386	8.4	2.9	5.6	3,330	5,270	966	.66	5.0	11.6	6,740	1,083	2.34	50
395	9.2	4.1	6.4	2,660	4,760	879	.47	4.9	12.4	6,160	979	2.13	50
433	11.5	4.3	7.3	3,180	5,180	1,111	.52	4.3	15.6	7,070	1,115	2.51	50
435	9.9	3.8	5.8	3,310	5,460	1,053	.59	6.0	12.0	6,910	1,203	2.20	50
391	7.8	2.2	5.9	3,410	5,310	1,073	.62	5.9	13.3	6,490	1,156	2.06	50
....	.....	.....	.....	4,530	6,560	1,024	.....	.....	.....	.....	.....	.....	....
....	.....	.....	.....	5,020	7,460	1,101	.....	.....	.....	.....	.....	.....	....
459	10.5	3.7	6.9	2,740	4,550	866	.50	4.8	6.1	6,300	1,076	2.09	50
435	10.3	3.0	6.2	2,180	3,850	798	.36	5.0	6.5	5,350	906	1.75	50
....	.....	.....	.....	3,440	5,820	1,143	.62	6.0	.....	.....	.....	.....	....
....	.....	.....	.....	3,160	5,200	968	.58	6.6	.....	.....	.....	.....	....
58	13.6	3.7	7.4	4,200	7,170	1,236	.84	7.2	30.0	7,750	1,263	2.67	50

ue to the fact that some of the tests were made before the more comprehensive series at present under way was institu

4,100	64	54	.667
4,270	67	55	.667
3,520	63	52	.667
4,160	62	65	.608
2,840	71	58	.646
2,780	63	64	.617
3,730	64	60	.653
3,240	66	74	.630
4,300	84	53	.695
.....	.....	.....	.....
3,040	.....	69	.512
.....	.....	57	.546
.....	.....	56	.577
2,780	61	.....	.....
2,540	62	64	.590
2,290	64	83	.569
2,670	70	80	.568
3,470	71	90	.565
.....	.....	74	.637
2,400	.....	88	.585
3,150	65	58	.594
	60	62	.603
3,030			
2,870	67	78	.600
.....	71	77	.573
3,980	.....	80	.550
2,320	82	31	.761
2,280	.....	81	.454
	26	121	.475
1,420			
2,710	36	55	.293
3,560	.....	80	.363
	38	79	.452
1,660			
2,763	14	47	.306
2,390	34	117	.383
2,610	22	32	.418
2,110	30	156	.350
	31	129	.340
2,290			
1,910	17	44	.370
3,420	14	58	.371
2,470	37	63	.528
.....	41	54	.440
2,340	.....	52	.477
1,900	34	123	.360
2,100	26	98	.353
2,250	31	125	.377
2,370	20	93	.391
3,420	31	74	.363
3,560	24	81	.334
	32	69	.366
1,880			
1,590	16	45	.325
.....	13	156	.299
.....	24	31	.396
3,010	22	41	.318
	38	52	.491

Blank spaces in the table

MECHANICAL PROPERTIES OF WOODS GROWN IN THE UNITED STATES.

THE TESTS.

The tests made by the Forest Service to determine the mechanical properties of woods grown in the United States fall into two classes: (1) Tests on full-sized pieces, such as bridge stringers and car sills, and (2) tests on small clear pieces free from defects. Tests of the first kind have been made on a number of species and the results presented in several publications. (See list on p. 4.) These results are of value in the formulation of grading rules for structural timber, in the establishment of working stresses, and in showing the influence of defects such as knots, shakes, and checks upon the strength of the material.

A series of tests of the second kind was begun by the Forest Service about two years ago to secure information that will enable the mechanical properties of the different woods to be compared, both in the green and air-dry state, and to determine the influence on strength of such factors as locality of growth, height of test pieces in the tree, and distance of pieces from pith. This preliminary circular gives in condensed form the average values thus far obtained from 49 species of wood tested in a green condition. More detailed analyses of the values will follow as the work progresses. The test material was cut from typical trees selected by members of the Forest Service, and records were made of the conditions of growth. Eventually each important species will be represented by averages from at least five typical trees from each of several localities throughout its range of growth. In several of the species listed in Table 1 averages are given from tests on less than five trees. Since there is considerable variation in the strength of wood from individual trees of the same species, such results should be taken as indications rather than as fixed values. The number of test pieces from each tree varied from 40 to 120, depending on the size of the tree. The total number of tests represented in Table 1 is about 25,000.

The tests, which comprise the series described above and others made previously, were made at laboratories of the Forest Service maintained in cooperation with the University of Wisconsin, Purdue University, University of Colorado, University of California, and University of Washington.

THE RESULTS.

Table 1 gives average values obtained from tests on green material 2 by 2 inches in cross section. The following kinds of tests were made: Bending, both static and impact; compression parallel and compression perpendicular to the grain; hardness; shear parallel to grain; cleavage or splitting; and tension at right angles to grain. The table also includes information on shrinkage, specific gravity, moisture content when tested, proportion of summerwood, and rate of growth or rings per radial inch.

LIST OF FOREST SERVICE PUBLICATIONS ON MECHANICAL AND PHYSICAL PROPERTIES OF WOOD.

BULLETINS.

Bul. 6. Timber Physics, Part I, Preliminary Report.[1]
8. Timber Physics, Part II, Progress Report.[1]
10. Timber—an Elementary Discussion of the Characteristics and Properties of Wood.[1]
13. Timber Pines of the Southern United States.
58. The Red Gum.
70. Effect of Moisture Upon the Strength and Stiffness of Wood.[1]
80. The Commercial Hickories.
88. Properties and Uses of Douglas Fir.
108. Tests of Structural Timbers.[1]
115. Mechanical Properties of Western Hemlock.
122. Mechanical Properties of Western Larch.

CIRCULARS.

Cir. 12. Southern Pine—Mechanical and Physical Properties.[1]
15. Summary of Mechanical Tests on Thirty-Two Species of American Woods.[1]
38. Instructions to Engineers of Timber Tests (Revised).
39. Experiments on the Strength of Treated Timber.
108. Strength of Wood as Influenced by Moisture.[1]
115. Second Progress Report on the Strength of Structural Timber.
142. Tests of Vehicle and Implement Woods.
164. Properties and Uses of Southern Pines.
179. Utilization of California Eucalypts.
189. Strength Values for Structural Timbers.[1]
193. Mechanical Properties of Redwood.

[1] Not available for free distribution, but can be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C.

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HENRY S. GRAVES, Forester.

FOREST PRODUCTS LABORATORY SERIES.

TESTS OF PACKING BOXES OF VARIOUS FORMS.

BY

JOHN A. NEWLIN,
Engineer in Forest Products.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1913.

FOREST SERVICE.

HENRY S. GRAVES, *Forester.*
ALBERT F. POTTER, *Associate Forester.*
HERBERT A. SMITH, *Editor.*

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3.	Results of tests	10
4.	Results of tests	11

TESTS OF PACKING BOXES OF VARIOUS FORMS.

PURPOSE AND SCOPE OF THE TESTS.

A large amount of wood now wasted could be saved through improvement in the design of packing boxes. The matter, however, is important not only from the standpoint of a better utilization of forest products, but also from that of the shipper, who suffers annually great loss through damage to goods in transit, due to inferior containers, and from that of the box manufacturer, who wishes to reduce costs.

A box made entirely of high-grade or expensive lumber may not be as serviceable as one made in part at least of inferior material. Moreover, if any part of a box is unnecessarily rigid the remaining parts will be subjected to undue stress, and it is therefore not only possible to waste material by making some part exceptionally heavy, but at the same time actually to produce an inferior box.

The tests described in this circular were made in cooperation with the Bureau for the Safe Transportation of Explosives and Other Dangerous Articles, at the Forest Products Laboratory, maintained in cooperation with the University of Wisconsin, Madison, Wis. Only a few types of boxes were tested, and the work completed covers but a small part of the field of box construction. The methods used at the laboratory are given in sufficient detail, however, to serve as a guide to manufacturers and users of boxes who wish to continue and extend the work.

MATERIAL TESTED.

Ninety-six boxes were tested, of which 24 were nailed, 32 were wire bound, and 40 were dovetailed. In each case one-third the number were "small," one-third "medium," and one-third "large," the capacity of each size being, respectively, 6, 12, and 20 one-gallon cans, 4 by 6 inches in cross-section, and made of 30-gauge (U. S. standard) tin. The boxes are described in detail in Tables 6, 7, and 8. Before being tested each box was carefully described in regard to the following points: Style or design; size (inside) and capacity; character and thickness of material; kind, size, and spacing of nails; apparent condition; weight (1) of box, (2) of contents; and arrangement of contents.

METHODS OF TEST.

Diagonal compression, endwise compression, and drop tests were made. These show the relative strength of the boxes when subjected to stresses which are distributed more or less throughout the box. They do not show the ability of the boxes to resist local fracture, such as might be caused by one box falling cornerwise on top of another. Resistance to a stress of this kind depends chiefly upon the strength of the board receiving the blow.

Not all the tests were conducted strictly in accordance with the plan which follows, since some were made before all the details of the method were developed. At the beginning, in the drop tests, each box was dropped from a height of 48 inches a sufficient number of times to cause complete failure. A few tests demonstrated that this was too severe, and the drop was changed to 36 inches. Later the increment plan was adopted.

Each box was filled to its capacity with cans of water of the size and style described under "Material tested."

ENDWISE-COMPRESSION TEST.

In the endwise-compression tests the box was compressed between two flat surfaces in the direction of its longest dimension. The rate of compression was 0.065 inch per minute. The test was discontinued when, after passing the maximum load, the box failed to sustain 50 per cent of this load.

This test yields load, compression, and work values, though these are less significant than those obtained from the diagonal test, since all parts of the box are not under stress. In endwise compression they depend largely upon the character and thickness of the material composing the sides, top, and bottom. The construction of the box plays a relatively unimportant part, though it may affect the tendency of the sides to buckle. The end bearing of the box may affect the results to some extent.

DIAGONAL-COMPRESSION TEST.

In the diagonal-compression test (see fig. 1) the box was compressed in the direction of a line connecting diagonally opposite corners. The rate of compression was 0.50 inch per minute. The test was discontinued when, after passing the maximum load, the box failed to sustain 50 per cent of this load.

The diagonal-compression test produces stress in every part of the box to a greater extent than do either of the two other tests. It is the measure of the ability of the box to resist a slowly applied or continuous steady load. The principal values obtained are the maximum load, compression at maximum load and at the end of the

test, and the computed values of work from the beginning to the maximum load and to the end of the test, respectively. These latter are graphically represented by the areas under the curve in the

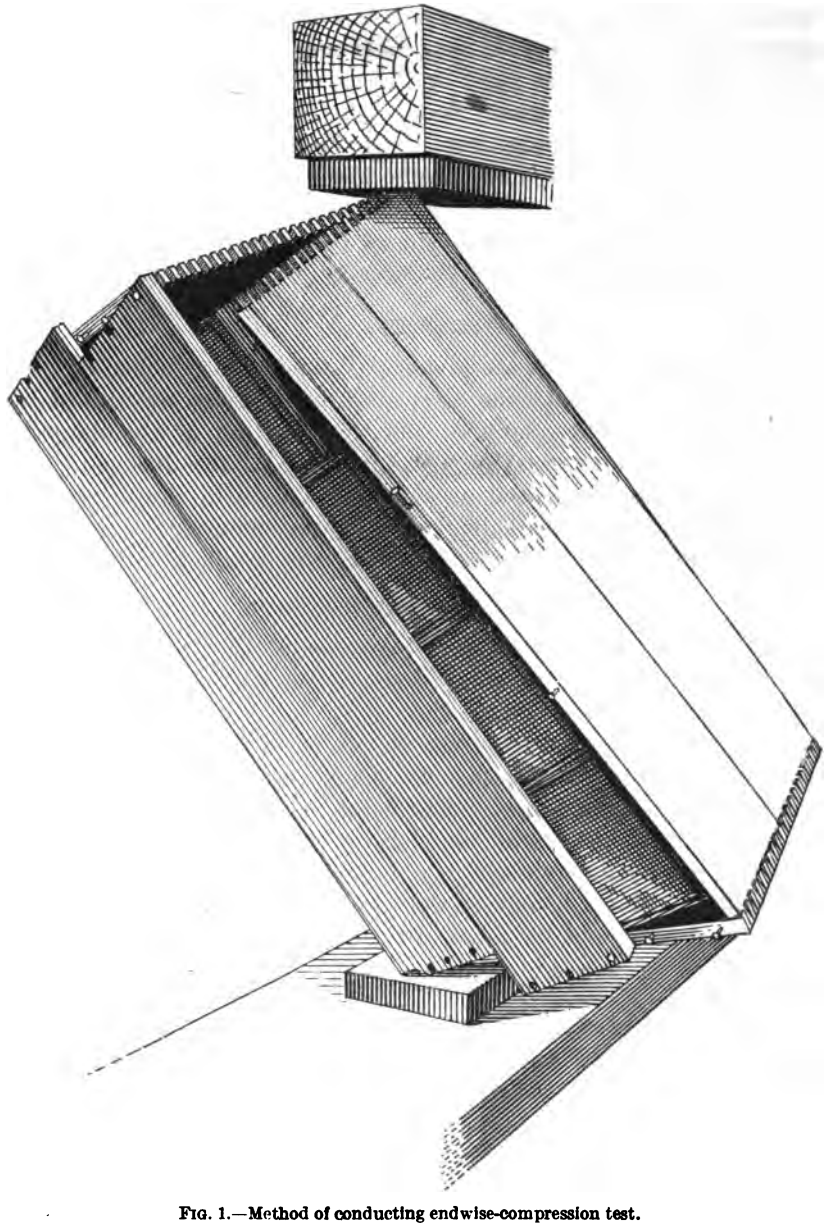


FIG. 1.—Method of conducting endwise-compression test.

load-compression diagram. The work values are the measure of the shock-resisting ability of the box. The compression shows the amount of deformation of the box for various loads.

DROP TEST.

In the drop test (see fig. 2) the box was suspended with its diagonally opposite corners in a vertical line, then allowed to drop through a distance of 1 foot upon a platform 2 feet square and approximately 3½ inches thick, consisting of two thicknesses of plank nailed together at right angles to each other. The platform rested directly upon a cement floor. The test was continued, adding 6 inches to each preceding drop, until the cans fell from the box.

This test approaches more nearly the conditions of service than either of the other tests. It does not, however, yield similar mathematical results, and a comparison of the behavior of the various types of boxes tested must be based largely upon the character and amount of the failures.

RESULTS.

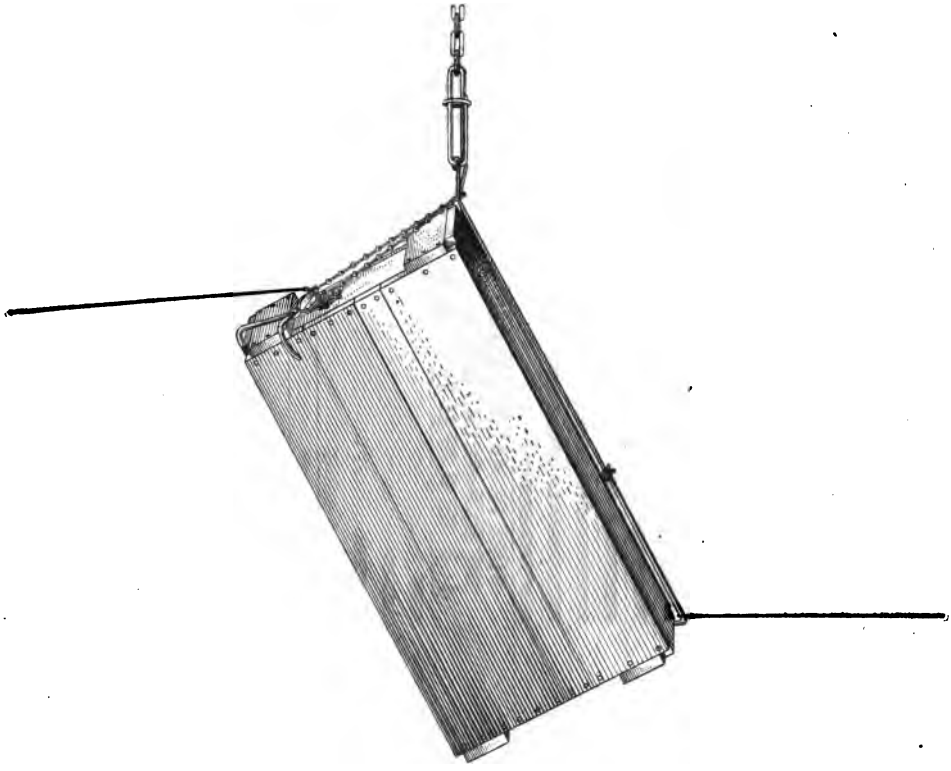
The results of the tests are given in Tables 1 to 5, inclusive. The principal ones obtained from the compression tests are also shown graphically in figures 3 and 4. In that portion of the diagrams showing work to maximum load values, the actual values computed from the tests are indicated by the total length of the lines. The solid black portion represents these values reduced to a basis of boxes of 6 gallons capacity—the size of the smallest tested.

ENDWISE-COMPRESSION TEST.

Most of the nailed boxes were constructed with two battens on each end, so that only the sides of the box had good bearing in this test. Thus, the loads which the boxes would support were less than might be expected from the thickness of the material used in their construction. Resistance to shock, however, would not be effected in the same degree. The wires of the wire-bound boxes, to a large extent, prevented buckling of the sides and caused these boxes to give results relatively high for the thickness of material. The absolute values, however, were lower for the wire-bound than for the dovetailed and for most of the nailed boxes.

DIAGONAL-COMPRESSION TEST.

In the diagonal-compression test (fig. 4) the dovetailed boxes with thick ends and the wire-bound boxes withstood about the same loads. The dovetailed boxes with thin ends and the nailed boxes gave much lower values. In work to maximum load (shock-resisting ability) the dovetailed boxes with thin ends gave exceedingly low values. Those with thick ends gave much higher values, yet not as high as were given by the nailed boxes other than those with single-piece ends. The wire-bound boxes showed much the highest work values. In stiffness, or rigidity, the dovetailed boxes were much superior to others tested. This is shown by the lower values for compression at maximum load (Table 2).



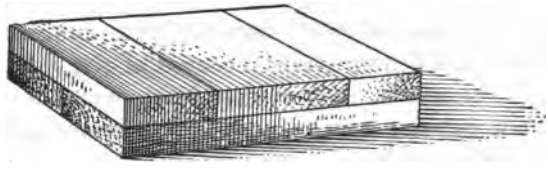


FIG. 2.—Method of conducting drop test.

DROP TEST.

In the drop test two forms of construction gave very poor results—the nailed boxes with single-piece ends and the dovetailed boxes with thin ends. The wire-bound boxes showed great ability to withstand the drop test, and far surpassed the nailed boxes in this

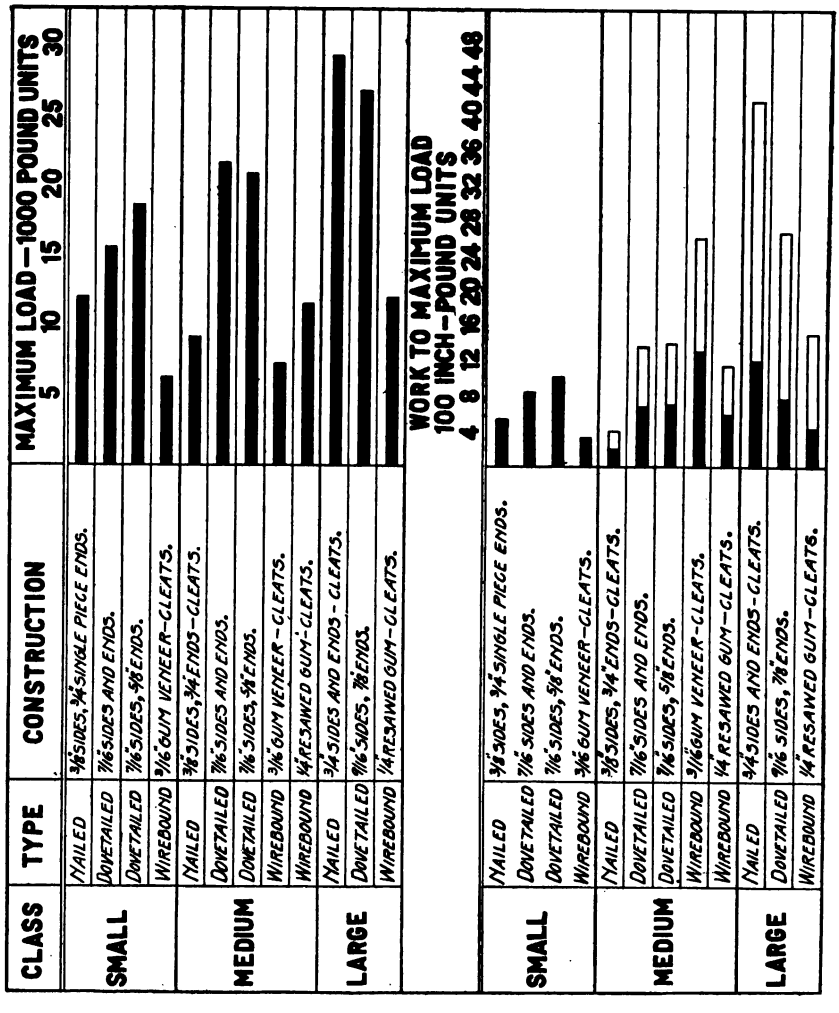


FIG. 3.—Results of tests.

respect. It is not possible very accurately to compare the dovetailed boxes with the others tested because of the difference in the height of drop. However, it is evident that even those with thick ends were much inferior to the wire-bound boxes and somewhat inferior to the nailed boxes with cleated ends.

CHANGES IN DESIGN AS INDICATED BY CHARACTER OF FAILURES.

The values resulting from the tests do not necessarily apply to all nailed, wire-bound, and dovetailed boxes, since changes in material or design may very greatly alter the strength.

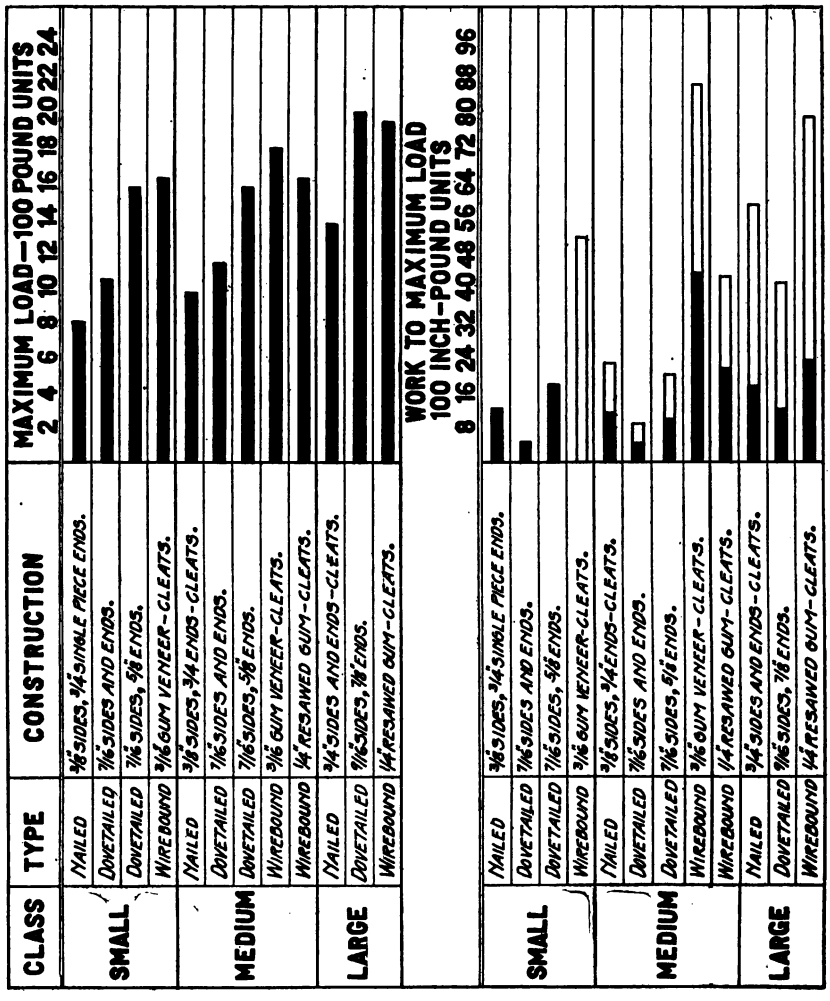


FIG. 4.—Results of tests.

NAILED BOXES.

The failure of nailed boxes with single-piece ends, without cleats, show this to be a very poor construction, since in 12 out of 18 such boxes subjected to drop or diagonal compression tests both ends were split completely in two, while in 4 of the remaining 6 boxes one end was split. The nails driven into the end grain of the boards showed very slight resistance to withdrawal.

In the case of boxes with cleated ends, failures did not occur in that portion of the box. The chief source of weakness was the withdrawal of the nails holding the top, bottom, and sides to the ends. An end made of thinner boards and with four cleats of a wood of greater nail-holding power would probably give much better results.

All of the nailed boxes were especially good in respect to workmanship and quality of material, and none of the failures can be attributed to defects. The tests, however, do not justify the condemnation of all nailed boxes. They merely show that the single piece is a very poor construction and indicate the necessity of using for certain parts a wood that will resist the withdrawal of nails.

WIRE-BOUND BOXES.

Wire-bound boxes showed a well-balanced construction. The top, bottom, and sides were held firmly to the ends by the wires and by staples driven into red gum cleats. The boxes had no especially weak points, although the ends of the cleats usually broke. This could probably be remedied by reenforcing the ends of the cleats or by changing their design.

The strength of the wire-bound boxes increases with the increase in the thickness of the lumber and with the size of wire or number of wires. In all of the tests the wires were an important element of strength.

DOVETAILED BOXES.

The thin end dovetailed boxes showed an unbalanced construction, since the joints did not hold. The thick-end boxes were much better. In both cases the tongue-and-groove joints were weak features of construction. When the joints in adjacent sides and ends were in the same or nearly the same plane the box was materially weakened. One such box (No. 34), which, with its contents, weighed 205 pounds, was pulled in two by being lifted by the upper corner to tilt it from the floor. The greater rigidity of these boxes resulted in less damage to the contents when the box failed completely than was the case with any of the other boxes.

TABLE 1.—*Detailed summary of endwise-compression tests.*

Description of boxes.					Result of tests.		
Type.	Class.	Material.	Box No.	Weight.	Maximum load.	Compression at maximum load.	Work to maximum load.
				Pounds.	*Pounds.*	*Inch.*	*In. lbs.*
Nailed	Small	White pine, $\frac{3}{8}$" sides, $\frac{3}{4}$" ends	1	6.5	13,000	0.075	384
			5	6.5	10,960	.105	712
		Average		6.5	11,980	.090	548
Wire-bound	do	$\frac{1}{16}$" red gum veneer	9	5.0	5,520	.110	344
			13	5.0	7,000	.084	320
		Average		5.0	6,260	.097	332
Dovetailed	do	White and Norway pine, $\frac{7}{16}$" sides and ends.	41	6.5	14,000	.093	600
			45	7.5	17,000	.146	1,080
		Average		7.0	15,500	.120	840
Do	do	White and Norway pine, $\frac{7}{16}$" sides, $\frac{3}{8}$" ends.	49	7.5	18,000	.095	810
			53	7.5	19,000	.135	1,230
		Average		7.5	18,500	.115	1,020
Nailed	Medium	White pine, $\frac{3}{8}$" sides, $\frac{3}{4}$" ends	17	10.5	11,000	.079	424
			21	10.0	7,280	.092	376
		Average		10.25	9,140	.086	400
Wire-bound	do	$\frac{1}{16}$" red gum veneer	25	7.5	7,090	.530	3,168
			29	8.0	7,430	.340	2,064
		Average		7.75	7,260	.435	2,616
Do	do	$\frac{1}{4}$" resawed red gum	33	10.5	11,480	.150	1,144
			37	10.5	11,700	.160	1,176
		Average		10.5	11,590	.155	1,160
Dovetailed	do	White and Norway pine, $\frac{7}{16}$" sides and ends.	1	11.5	22,000	.175	1,560
			5	11.5	21,000	.165	1,080
		Average		11.5	21,500	.170	1,320
Do	do	White and Norway pine, $\frac{7}{16}$" sides, $\frac{3}{8}$" ends.	9	11.5	16,500	.170	1,200
			13	12.5	25,000	.130	1,500
		Average		12.0	20,750	.150	1,350
Nailed	Large	White pine, $\frac{3}{8}$" sides and ends	41	24.5	27,400	.280	4,032
			45	25.5	30,900	.290	4,288
		Average		25.0	29,150	.285	4,160
Wire-bound	do	$\frac{1}{4}$" resawed red gum	49	13.5	11,700	.220	1,536
			53	14.0	12,300	.245	1,504
		Average		13.75	12,000	.232	1,520
Dovetailed	do	White and Norway pine, $\frac{9}{16}$" sides, $\frac{3}{8}$" ends.	33	20.0	26,100	.215	2,790
			37	21.0	27,000	.225	2,560
		Average		20.5	26,550	.220	2,675

TABLE 2.—*Detailed summary of diagonal-compression tests.*

Description of boxes.					Results of tests.					Description of failure.
Type.	Class.	Material.	Box No.	Weight.	Maximum load.	Compression at maximum load.	Total compression.[1]	Work to maximum. load.	Total work.[1]	
				Lbs.	*Lbs.*	*Inches.*	*Inches.*	*In.-lbs.*	*In.-lbs.*	
Nailed.....	Small.....	White pine, $\frac{3}{8}$" sides, $\frac{3}{4}$" ends.	2	6.75	920	2.2	4.55	1,344	2,950	Shearing of sides; pulling of nails; splitting of end.
			6	6.25	840	2.7	4.40	1,580	2,680	Gradual failure by shearing of sides and pulling of nails.
			8	5.75	620	1.3	5.87	560	2,930	Splitting of ends.
		Average.....	.....	6.25	793	2.1	4.94	1,161	2,853	
Wire-bound..	...do	$\frac{1}{16}$" red gum veneer.....	10	4.75	1,480	8.4	10.40	9,800	12,120	Splitting of cleats at mortises; pulling of staples, and buckling and splitting of veneer.
			14	5.00	1,930	3.0	6.18	3,280	8,300	Pulling of veneer from cleats and splitting at season checks; pulling of staples from cleats.
			16	5.00	1,400	2.8	3.65	2,300	3,300	Splitting of cleats at mortises; untwisting of wires.
		Average.....	.....	4.92	1,603	4.7	6.74	5,127	7,906	
Dovetailed...	...do	White and Norway pine $\frac{7}{16}$" sides and ends.	42	7.5	940	.60	1.05	340	680	Slipping of dovetails; splitting of ends; pulling off of top.
			46	7.5	1,210	.80	1.05	640	860	Do.
			48	7.5	950	.60	.80	380	500	Slipping of dovetails; pulling of nails from sides.
		Average.....	.....	7.5	1,033	.67	.97	453	680	
Do.....	...do	White and Norway pine $\frac{7}{16}$" sides—$\frac{3}{8}$" ends.	50	7.5	1,850	2.80	3.05	3,770	4,140	Shearing of top (partially split before test); opening of dovetail; pulling of nails from end.
			54	8.0	1,450	.90	1.20	760	1,080	Pulling loose of top; opening of dovetail at corner.
			56	7.5	1,390	.80	.98	680	860	Opening of dovetails and splitting off of bottom.
		Average.....	.....	7.7	1,563	1.17	1.74	1,737	2,027	
Nailed.....	Medium...	White pine, $\frac{3}{8}$" sides, $\frac{3}{4}$" ends.	18	11.0	1,020	3.4	5.50	2,480	4,280	Shearing of sides and pulling of nails.
			22	11.0	890	3.7	7.50	2,440	4,820	Do.
			24	10.5	960	2.8	7.50	1,840	5,520	Do.
		Average.....	.....	10.83	957	3.3	6.83	2,253	4,873	

Wire-bound..	Medium...	$\frac{1}{16}$" red gum veneer.....	26	8.0	1,610	5.8	7.30	7,140	8,930	Splitting of cleats at mortises, pulling of staples from cleats, breaking of two interior wires.
			30	8.0	1,900	5.8	9.68	6,960	12,800	Splitting of cleats at mortises; splitting of veneer at end; breaking of two end and two interior wires (interior wires loose at beginning of test).
			32	9.0	1,840	9.9	11.40	11,820	14,150	Splitting of cleats at mortises; splitting of veneer; and breaking of wires.
		Average.....		8.33	1,783	7.2	9.46	8,640	11,960	
Do.....	...do	$\frac{1}{4}$" resawed red gum.....	34	10.75	1,510	3.1	4.80	2,640	4,910	Shearing at sides; splitting of cleats; breaking of wires.
			38	10.50	1,490	4.8	5.75	4,910	6,170	Shearing at sides; splitting of cleats; pulling of staples; breaking of wires.
			40	10.50	1,820	4.6	6.40	5,130	7,810	Splitting of cleats at mortises; pulling of staples; breaking of wires.
		Average.....		10.58	1,607	4.2	5.65	4,227	6,297	
Dovetailed...	...do	White and Norway pine, $\frac{1}{16}$" sides and ends.	2	10.5	1,180	.80	1.10	640	900	Pulling of nails and failure of dovetail at lower end.
			6	11.0	860	2.00	2.20	1,190	1,330	Splitting of upper end and side at joint in side; opening of dovetail at lower edge; splitting of lower end in plane of previous splits, followed by splitting at ends of other side; pulling of nails from one edge of upper side.
			8	11.5	1,340	.80	1.10	620	950	Pulling of nails from sides and ends of top, followed by slipping of dovetail at lower corner.
		Average.....		11.0	1,127	1.20	1.47	817	1,060	
Do.....	...do	White and Norway pine, $\frac{1}{16}$" sides, $\frac{3}{8}$" ends.	10	11.0	1,720	2.00	2.40	2,410	3,020	Shearing in joints of bottom, pulling of nails, and opening of dovetail, pulling loose of bottom along one side and end.
			14	11.5	1,800	1.10	1.30	1,150	1,480	Slipping of dovetail and pulling of nails along one side and one end of bottom.
			16	12.0	1,180	2.50	2.66	2,340	2,470	Shearing of side, followed by splitting of side and end. Box split entirely around.
		Average.....		11.5	1,567	1.87	2.12	1,967	2,323	
Nailed.....	Large.....	White pine, $\frac{3}{4}$" sides and ends.	42	25.5	1,350	8.7	9.00	8,080	8,370	Shearing of sides and pulling and splitting out of nails.
			46	26.0	1,410	5.2	9.60	4,800	9,970	Do.
			48	26.0	1,310	5.1	8.30	4,800	7,790	Do.
		Average.....		25.8	1,357	6.3	8.97	5,893	8,710	

[1] The test was terminated when the load, after having passed the maximum, reached one-half the maximum.

TABLE 2.—*Detailed summary of diagonal-compression tests*—Continued.

Description of boxes.					Results of tests.					Description of failure.
Type.	Class.	Material.	Box No.	Weight.	Maximum load.	Compression at maximum load.	Total compression.	Work to maximum load.	Total work.	
				Lbs.	*Lbs.*	*Inches.*	*Inches.*	*In.-lbs.*	*In.-lbs.*	
Wire bound..	Large.....	⅛" resawed red gum.....	50	14.0	2,150	6.7	.....	8,570	.....	Splitting of cleats at mortises; shearing of sides.
			54	14.75	1,910	6.1	7.60	8,220	9,860	Shearing of sides; splitting of cleats at mortises.
			56	15.5	1,730	5.9	.....	6,830	.....	Shearing of sides; splitting and breaking of cleats; pulling of staples.
		Average.....	.....	14.75	1,930	6.2	7.60	7,873	9,860	
Dovetailed...	...do	White and Norway pine, $\frac{5}{16}$" sides, $\frac{7}{8}$" ends.	34		Cull					This box pulled in two in handling, and was not tested.
			38	20.5	1,460	5.90	12.10	3,390	6,360	Shearing of top and bottom; splitting of nails out of end; opening of dovetails; splitting of end and side (joint of top open before test).
			40	20.0	2,510	5.90	8.00	4,720	6,678	Shearing of top and bottom, splitting of upper end, and opening of dovetail.
		Average.....	.....	20.2	1,985	5.90	10.05	4,055	6,519	

TABLE 3.—*Detailed summary of drop tests, 36-inch drop, nailed and wire-bound boxes.*

Description of boxes.						Total number of drops.	Condition of box.		
Type.	Class.	Material.	Box No.	Weight.			After first drop.	After second drop.	After third drop.
				Box.	Box and contents.				
				Lbs.	*Lbs.*				
Nailed	Small	White pine, $\frac{3}{8}$" sides, $\frac{3}{4}$" ends.	7	6.5	62.5	1	Both ends split; box broken entirely in two; no leakage from cans.		
Wire-bound	do	$\frac{3}{16}$" red-gum veneer	15	5.5	60.0	3	Cleat split at striking corner; veneer of lower end split; staples pulled from cleats; cleats at upper end split.	Further pulling of staples at lower end; increase of failure at upper end.	Further increase of previous failures; one can leaking.
Nailed	Medium	White pine, $\frac{3}{8}$" sides, $\frac{3}{4}$" ends.	23	11.0	121.0	1	Nails pulled at both ends; side boards nearly loose at lower end; cans leaking.		
Wire-bound	do	$\frac{3}{16}$" red-gum veneer	27	8.5	119.0	1	One cleat at lower end broken; side veneer near striking corner splintered; defective can leaking.		
Do	do	do	28	8.0	120.0	1	Veneer and cleat at striking corner broken; veneer of top split; cleats at upper end split; cans leaking.		
Do	do	$\frac{1}{4}$" resawed red gum	35	10.5	122.0	3	Side veneer broken near point of impact; 1 cleat at lower end broken.	Another cleat at lower end broken; staples pulled from 3 cleats; 1 cleat at upper end broken.	Other 2 cleats at lower end broken; sides coming apart at striking corner; 1 wire broken; 1 can leaking.
Do	do	do	36	10.0	122.5	2	Cleats at both ends split; staples drawn from bottom and one side cleat at lower end.	Bottom out; cans leaking.	
Nailed	Large	White pine, $\frac{3}{4}$" sides and ends.	44	26.0	208.5	1	Lower end broken into two; top and one side board broken loose; cleats at upper end broken; cans fell out.		
Do	do	do	47	25.5	209.0	1	Top and bottom boards sheared; nails pulled from both ends; cans leaking.		
Wire-bound	do	$\frac{1}{4}$" resawed red gum	52	13.5	191.0	1	Bottom loose; cleats broken; cans leaking.		
Do	do	do	55	13.5	198.0	2	Frame of lower end broken; staples pulled at one corner; lower end boards split; shear of side boards; staples pulled from cleat at upper end.	Lower end broken out; 4 cans fell out of box.	

TABLE 4.—*Detailed summary of drop tests, 48-inch drop, nailed and wire-bound boxes.*

Description of boxes.						Total number of drops.	Condition of box.			
Type.	Class.	Material.	Box No.	Weight.			Before test.	After first drop.	After second drop.	After third drop.
				Box.	Box and contents.					
				Lbs.	*Lbs.*					
Nailed	Small	White pine, $\frac{3}{8}$" sides, $\frac{1}{2}$" ends.	3	6.5	61.5	2		One end almost off; bottom split; 5 nails pulled from bottom; both sides and top split.	One can leaking considerably; first failure increased so that cans could fall out; 2 cans practically unhurt.	
Do	do	do	4	6.5	62.0	1		Two sides and both ends split completely; box separated into 2 pieces; 1 can leaking very slightly; 4 cans practically unhurt.		
Wire-bound	do	$\frac{1}{16}$" red-gum veneer.	11	5.5	60.5	3	Top and bottom checked; ends slightly checked; sides good.	One cleat at bottom almost off; 1 staple in this cleat nearly and 1 completely out; 1 top cleat split; veneer on 1 side split in 3 places.	Two bottom cleats almost off; 2 wires broken; 2 staples pulled out of veneer on side at bottom.	Cans leaking considerably; top veneer shattered; first failures increased.
Do	do	do	12	5.0	61.5	3	Veneer of both ends slightly checked; top and bottom checked once across.	One cleat at top end broken; veneer shattered at striking corner; 2 cleats at bottom split.	Bottom veneer shattered; 1 wire broken; same 2 cleats at bottom loose.	All 4 cleats at bottom loose; 1 can leaking; veneer on 1 side split.
Nailed	Medium	White pine, $\frac{3}{8}$" sides, $\frac{1}{2}$" ends.	19	11.0	122.5	2		One bottom cleat broken at end; 1 board of bottom split; top unhurt; both ends and 1 side split considerably.	Box broken into pieces; cans spilled out and leaking.	
Do	do	do	20	11.0	122.75	1		Bottom end broken across; 2 cleats at bottom end broken; 1 side pulled loose except along 1 end; half of other side pulled off; cans fell out and 1 leaking.		
Wire-bound	do	$\frac{1}{16}$" red-gum veneer.	31	5.5	119.5	2		Bottom veneer broken almost off; cleats apart; 2 cleats broken; side veneer broken at striking corner; 1 cleat at upper end broken and veneer slightly damaged; wire at lower end broken.	Increase of first failure; another wire broken; veneer on 2 sides split; 1 can leaking.	

Do	...do	¼" resawed red gum.	39	10.5	122.5	1		Two cleats at lower end broken; 1 cleat pulled loose from side; 1 cleat at upper end split; cans leaking.	
Nailed	Large	White pine, ¾" sides and ends.	43	25.0	208.0	1		Bottom entirely free from side; 1 side board loose at upper end; cans spilled out.	
Wire-bound	...do	¼" resawed red gum.	51	13.5	198.5	1		Bottom completely off; 1 cleat at top end damaged; cans out and leaking; sides and upper end not badly damaged.	

TABLE 5.—*Detailed summary of drop tests, increment drops, dovetailed boxes.*

Description of boxes.					Total number of drops.	Condition of box.			
Class.	Material.	Box No.	Weight. Box.	Weight. Box and contents.		After first drop (12 inches).	After second drop (18 inches).	After third drop (24 inches).	After fourth drop (30 inches).
			Lbs.	*Lbs.*					
Small.....	White and Norway pine, $\frac{1}{16}$" sides and ends.	43	6.5	63.0	2	Bottom pulled loose along lower end and one side, bottom split, upper end split, and piece loosened from dovetail.	Bottom completely off; cans fallen out.	.....	
Do.....	.....do.....	44	7.0	63.0	3	Bottom slightly loosened along upper end and one side.	Further loosening of bottom; lower end almost completely loose.	Bottom hangs to upper end only: lower end in three pieces and completely out; cans fallen out.	
Do.....	.....do.....	47	6.5	63.0	2	Bottom slightly loose along lower end and one side; lower end dovetail almost out.	Bottom hangs to upper end only; lower end completely out; cans fallen clear of box.	.....	
Do.....	White and Norway pine $\frac{1}{16}$" sides, $\frac{1}{2}$" ends.	51	7.5	64.0	4	Bottom loosened slightly....	Slight increase of first failure...	Further increase of first failure; upper end split; dovetail at lower end slightly loosened.	Bottom completely off; upper end split; cans fallen clear of box.
Do.....	.....do.....	52	7.5	64.0	3	No noticeable failure.....	Bottom loosened at side; dovetail at lower end slightly loosened.	One side and both ends split at joints; in same plane bottom pulled off with part of one side and each end adhering to it.	
Do.....	.....do.....	55	8.0	64.5	3	.....do.....	Bottom loose along upper end and one side; upper end split; dovetail at lower end open about $\frac{1}{2}$".	Bottom hanging only by splinters; increased opening of dovetail at lower end.	
Medium....	White and Norway pine, $\frac{1}{16}$" sides and ends.	3	10.5	122.0	2	Dovetail at lower end almost free; top loose along one side.	Lower end entirely out; cans fallen clear of box.	.....	
Do.....	.....do.....	4	10.8	122.5	2	Bottom split and loose along upper end and one side.	Bottom off and lower end out; cans fallen clear of box.	.....	
Do.....	.....do.....	7	11.7	124.0	2	One side split entire length: lower end split and dovetails loose.	Lower end in two pieces and entirely out; bottom entirely off; upper end split; cans fallen clear of box.	.....	

Do.....	White and Norway pine, $\frac{1}{16}$" sides, $\frac{1}{8}$" ends.	11	12.0	124.0	3	Bottom pulled from side slightly.	Lower end dovetail clear of one side; one side split and loose from bottom; upper end split along top.	Both ends split; top off with part of each end and one side adhering to it; other side clear of top and bottom; lower end dovetail clear of one side.	
Do.....	.....do.....	12	11.5	123.5	4	Top almost loose from one side; other side of top split along line of nails; bottom also split along one line of nails.	Dovetail free of one side at lower end; increase of first failure.	Top loose at upper end and along one side; previous failure of dovetail increased.	Box broken into two pieces: top and part of one end comprise one piece with remainder of box as other.
Do.....	.....do.....	15	12.5	125.5	3	Nails loosened along one side of bottom; dovetail loosened slightly at lower end.	Top loose along upper end and one side: lower end split at joint and dovetail pulled out; cans almost ready to fall out.	Box in three pieces; dovetails at one end entirely free; both ends split at joint; cans fallen from box.	
Large.....	White and Norway pine, $\frac{5}{16}$" sides, $\frac{1}{8}$" ends.	35	22.5	209.0	2	Bottom pulled loose at upper end; shear of top and bottom at joints.	One bottom board completely off; two other boards almost free at upper end; no failure of dovetails; cans fallen out.	.....	
Do.....	.....do.....	36	19.2	206.0	3	Bottom split along one line of nails; top slightly loose along one side.	Bottom loosened from upper end and one side; shear of top and bottom at joints; dovetails of lower end loosened slightly.	Bottom nearly off; one side cracked across; top split along nail line; dovetail failure of previous drop drop increased; cans fallen from box.	
Do.....	.....do.....	39	21.0	209.5	3	Shear of top and bottom at joints; bottom slightly loosened from end at 3 nail points.	Increase of first failures; one side split one-half its length from lower end; lower end split near bottom; lower end dovetail open about $\frac{1}{4}$".	One bottom board off; increased failure of lower end dovetail; cans fallen clear of box.	

TABLE 6.—*Detailed description of nailed boxes.*

Box Nos.	Class.	Average weight.	Inside dimensions.			Material.			Nails.		
			Width.	Depth.	Length.	Sides, top, and bottom.	Ends.	Cleats.	Sides, top, and bottom into ends and cleats.	Top and bottom into sides.	Cleats into ends.
		Pounds.	*Inches.*	*Inches.*	*Inches.*						
1 to 8	Small.....	6.4	8½	10¾	19	⅜" white pine, matched.	¾" white pine, single piece, grain horizontal.	None.....	Top, 5d. common; sides and bottom, 6d. box: all cement-coated.	3d. fine, cement-coated.	
17 to 24	Medium...	10.8	12¾	10¾	25½	.....do.....	¾" white pine, matched.	Two at each end, ⅞" by 1¾" white pine.	6d. box, bright and cement-coated.	.....do.....	5d. box, cement-coated.
41 to 48	Large.....	25.5	17	10¾	31½	¾" white pine, matched.	.....do.....	Two at each end, ¾" by 2¾" white pine.	8d. box, cement-coated.	8d. box, cement-coated.	Do.

TABLE 7.—*Detailed description of wire-bound boxes.*

Box Nos.	Class.	Average weight.	Inside dimensions.			Material.		Staples.			Wires.	
			Width.	Depth.	Length.	Sides, top, bottom, and ends.	Cleats.[1]	Holding end wires.	Holding interior wires.	Through ends into cleats and battens.	No.	Gauge.
		Pounds.	*Inches.*	*Inches.*	*Inches.*							
9 to 16....	Small.....	5.1	8½	10¾	19	$\frac{5}{16}$" red gum veneer, single piece.	4 at each end, ¾" by 1⅛" red gum.	1½" No. 16.	½" No. 18..	¾" No. 16..	4	15
25 to 32...	Medium...	7.8	12¾	10¾	25½	.....do.....	4 cleats and 1 batten at each end, ¾" by 1⅛" red gum.	...do.....	...do.....	...do.....	5	15
33 to 40...	...do.....	10.5	12¾	10¾	25½	½" resawed red gum, matched.	.....do.....	...do.....	⅝" No. 18..	...do.....	4	14
49 to 56...	Large.....	14.0	17	10¾	31½	.....do.....	.....do.....	1½" No. 16.	...do.....	¾" No. 16..	5	14

[1] In boxes Nos. 9 to 16 the ends of the horizontal cleats were notched to receive tenons on the ends of the vertical cleats. All other wire-bound boxes had the same end construction with the addition of a vertical batten at the center of each end. These battens were fitted between the horizontal cleats and were held by nails through the cleats into their ends.

TABLE 8.—*Detailed description of dovetailed boxes.*[1]

Box Nos.	Class.	Average weight.	Inside dimensions.			Thickness in inches of—		Nails.	
			Width.	Depth.	Length.	Sides, top, and bottom.	Ends.	Top and bottom into ends.	Top and bottom into sides.
		Pounds.	*Inches.*	*Inches.*	*Inches.*				
41 to 48	Small.....	7.1	8½	10¾	19	1/16	1/16	5d. box, cement-coated.....	4d. box, cement-coated.
49 to 56	...do.....	7.6	8½	10¾	19	1/16	3/32	.....do.....	Do.
1 to 8	Medium....	11.1	12¾	10¾	25½	1/16	1/16	.....do.....	Do.
9 to 16	Large.....	11.8	12¾	10¾	25½	1/16	3/32	.....do.....	Do.
33 to 40	...do.....	20.6	17	10¾	31½	1/16	1/8	6d. box, cement-coated.....	Do.

[1] The dovetailed boxes were of white and Norway pine. The ends, sides, tops, and bottoms were matched and glued except that a few were of one piece. The ¾-inch boards were double tongued and grooved.

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PITH-RAY FLECKS IN WOOD.

BY

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PITH-RAY FLECKS IN WOOD.

PREVIOUS INVESTIGATIONS.

Pith-ray flecks, or medullary spots, often render lumber unfit for certain uses. They are common in many of our native woods (Pl. I, fig. 1), appearing in transverse sections of logs or lumber as crescent-shaped, discolored areas, and in tangential, or bastard cut, boards as brown streaks running usually in a vertical direction (Pl. I, fig. 2). The pith rays, passing outward toward the cortex, end blindly in the discolored areas, and it is comparatively easy with a microscope to detect the connection of the two.

The observance of pith flecks appears to be coincident with the early systematic study of wood. Theodore Hartig, noting them as early as 1840 in *Corylus*, *Betula*, and *Alnus*, designated them "Zellgange," or cellular passages. He described them as similar to the passages of barkbeetles, extending down into the roots for 5 feet or more and up into the stem. The cells, he says, are rich in starch, and contain brown masses of an unknown substance insoluble in alcohol or water.

Ratzburg found similar markings in wood which he received from Russia in 1852. He suspected their pathologic origin and named them "Braunketten;" that is, "brown chains of cells." Nordlinger also called attention to them in his "Querschnitt von hundert Holzarten," but applied to them the name of "Markfleckchen." In spite of the generally accepted belief in the pathologic origin of these markings, attempts were made by some writers to use them to identify species. Kienitz published a key of the most important German woods, in which he endeavored to separate some species of *Prunus* and *Salix* by the presence of pith flecks.

Kienitz, in 1883, submitted the first convincing proofs of the pathologic origin of pith flecks. He found that they were due to the work of the larvæ of dipterous insects [1] living in the growing cambium and eating passages in this layer while in search of food. According to his observations the insect passes the winter in the pupal state in the ground. The adult forms appear in the spring and deposit their

[1] These insects consist probably of one or more species which as yet have not been classified and named.

eggs singly, apparently in the young branches of the tree. Kienitz, unfortunately, failed to observe the manner of entrance into the cambial layer, but found the young larvæ in infested trunks as early as May, eating passages in the cambium and in the soft tissue of the inner bark. At first these passages are narrow, only a few cells broad, and lead downward. As the larvæ proceed downward they grow but slightly in thickness, though considerably in length. Finally each one becomes 2 or 3 cm. long. The passage, Kienitz says, gradually widens as the insect grows in size. It spreads out laterally as the larva turns as far to left or right as its worm-shaped body will permit. In a radial direction the wound is always slight, since the larva attacks only the growing cells of the cambium. After it has proceeded a certain distance downward, the larva abruptly turns, and, without forming a loop, starts upward. The size of the passage is increased only slightly at this turning point.

The position of the turning point in the tree varies. Often it is at the dividing point between root and stem, or else in a lateral root. Sometimes the larva turns but once or twice, while in other cases it may turn a number of times. Finally it assumes a somewhat shorter and more compact form, bores through the bark, emerges from the narrow opening, and falls to the ground. Kienitz did not observe the adult form.

Investigations of the insects involved are being carried on by the Bureau of Entomology through its branch of forest insects.

ORIGIN OF PITH FLECKS.

The present investigation confirms the conclusion of Kienitz, published in 1883, that pith flecks are caused by the larva of a dipterous insect living in the cambium during the growing season. Specimens of river birch were examined as early in the season as April 25. Growth had then begun, as shown by the ease with which the bark peeled from the wood. At this time the larvæ were burrowing vertically downward in the cambium and had already reached a point about 6 feet above the ground. They were 1½ cm. long, 1 mm. in width, and pure white, except for the dark mouthparts.

To determine the manner in which the larvæ obtained entrance into the cambium, a number of mines were traced back to their source. This could be done with reasonable care, because at this early date growth had not progressed far enough to cover up or obliterate the mines. They had their origin invariably in the upper part of the tree's crown and on branches of about 5 years' growth. In such cases the mine could be traced to a suppressed lateral twig. At the point of attachment of this to the main branch, and always on the side toward the ground, a dark coloration could usually be detected extending from the outer bark into the cambium. This appeared

like a puncture of some sharp instrument. The coloration resulted from the decay of the injured cells. Whether the larva first hatches out of the egg outside the bark and then bores into the cambium, or whether the adult female deposits the egg in the cambium itself, can not be determined from the present investigation.

Observations were next made about two weeks later—that is, about May 10. The larvæ had increased slightly in length, but scarcely at all in diameter. Some had already reached the base of the tree and started back, following for a short distance a path parallel to the old mine, and then branching off obliquely (Pl. II, fig. 2). Very few had gone far down into the roots at this time, but were burrowing in the growing layer near the base of the tree. This was expected, since the larvæ were evidently guided in their movements by the food supply.

During May there were examined specimens of black cherry, wild plum, serviceberry, red maple, and wild apple. From all of these species larvæ were secured similar to those already described. The mines that were still free from wound tissue were readily followed as the bark was removed. Often the larvæ were secured by thus tracing a mine to its termination. The number of larvæ in each case varied with the tree species and individual. In Maryland and Virginia river birch appears to be the favorite host, with wild plum, serviceberry, black cherry, red maple, wild apple, and silver maple following in the order named. Certain specimens in a few localities were almost free from larvæ, while others seemed to be favorite hosts year after year, as shown by the number of pith flecks in previous rings of growth.

During the period between May 25 and June 25 the larvæ continued to mine back and forth, seldom going more than 10 feet above the ground. As the larva grew larger the mines gradually increased in diameter up to several millimeters and often crossed one another. The appearance of the wood was often misleading as to the number of larvæ actually at work, since one larva, working up and down, may make several flecks within the same annual ring.

Pupation began about June 25. After this date the time of pupation seemed to depend somewhat on the age of the tree. In young trees with relatively thin bark it occurred first, while larvæ were secured from older trees with thick bark as late as July 20. The larvæ proceeded down into the roots for varying distances. When the roots are exposed, as along the banks of streams, the mines often continue for a number of feet until they enter the ground. In trees growing on flat land the roots are seldom penetrated for more than 3 feet. In such instances the larvæ generally return to a position near the base of the trunk and pass out through the cortex.

Pupation takes place in the ground. The larvæ bore a small hole through the bark and come out in the earth. The end of a mine is

generally marked by a small black spot where the cambium is exposed to the air. A number of puparia were secured in proximity to the bark and always close to the termination of a mine. Pupation occurred, as already stated, almost immediately after the larva emerged.

OCCLUSION OF THE LARVAL PASSAGES.

Soon after the passage of the larva the healing process begins. The larva destroys only those cells in its immediate path through the inner bark. Cambial activity proceeds as usual on both sides of the passage. As the cambium layer moves outward radially, the passage left by the larva increases in diameter. For this reason, when growth is very rapid, the pith-fleck spots are larger than when it is slow. Mines produced in early spring are larger radially than those made later in the season, when diameter increase is slower.

The healing process proceeds mainly from the bast pith-ray cells in the bark which are in direct communication with the reserve food supply. During this healing process made by the division of the bark cells toward the wood, growth is proceeding in the cambium on each side of the wound. The cambium becomes united again toward the periphery of the annual ring, and wood elements are formed in the usual way. Thus the cambium, reuniting around the passage, leaves the latter behind in the annual ring. And the passage, although thus wholly independent of the new cambium, becomes filled with new cellular tissue. This process can be followed macroscopically by removing the bark from the infested trees. For a short distance back of the larva the mine is free of all cell growth, and appears like a small groove under the bark. Soon, however, wound tissue is formed, and the space is filled with young cells similar in character to those in pith rays. This tissue clings to the inner bark when the latter is removed from the tree, and appears like a ridge upon the smooth surface. After a distance of a few feet the wound tissue gradually passes over into the wood or older portion of the annual ring. The farther the mine is traced backward the deeper is it buried, and in fast-growing trees it often disappears completely in the wood.

Some idea of the microscopic appearance of pith flecks in transverse section may be had from Plates II, III, and IV. The thick-walled cells are occasionally separated by layers of a compact, yellowish-brown substance, the remains of dead cells and excrement of larvæ. The size of the cells filling the wound does not depend upon the size of the wound itself, but upon the nature of the tissue surrounding the wound; that is, upon the size of the ray cells and the diameter of the vessels. Where the ray cells are compact and short, such as in wild plum (Pl. III, fig. 1), the successive divisions in the healing process give rise to cells of small dimensions. But when they are

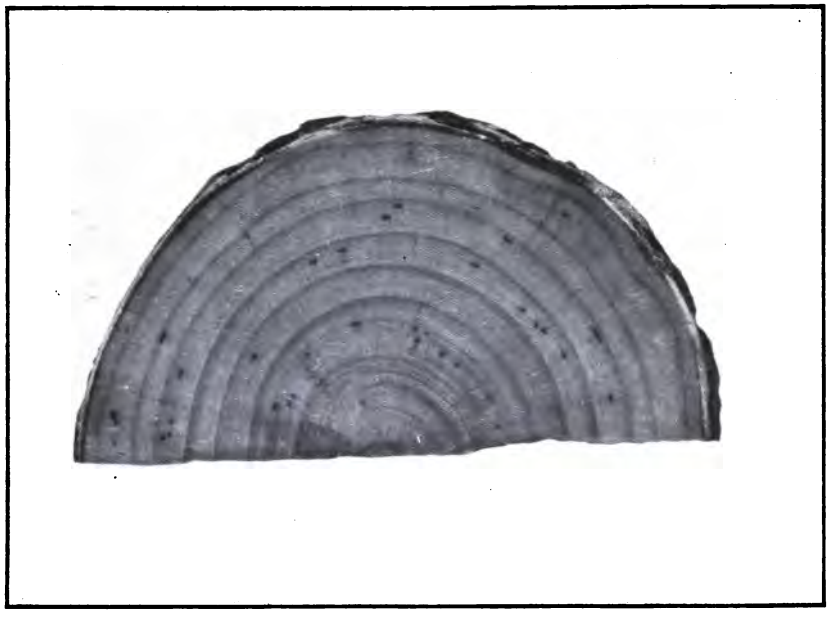


FIG. 1.—TRANSVERSE SECTION OF A BRANCH OF RIVER BIRCH, SHOWING PITH FLECKS. NATURAL SIZE.

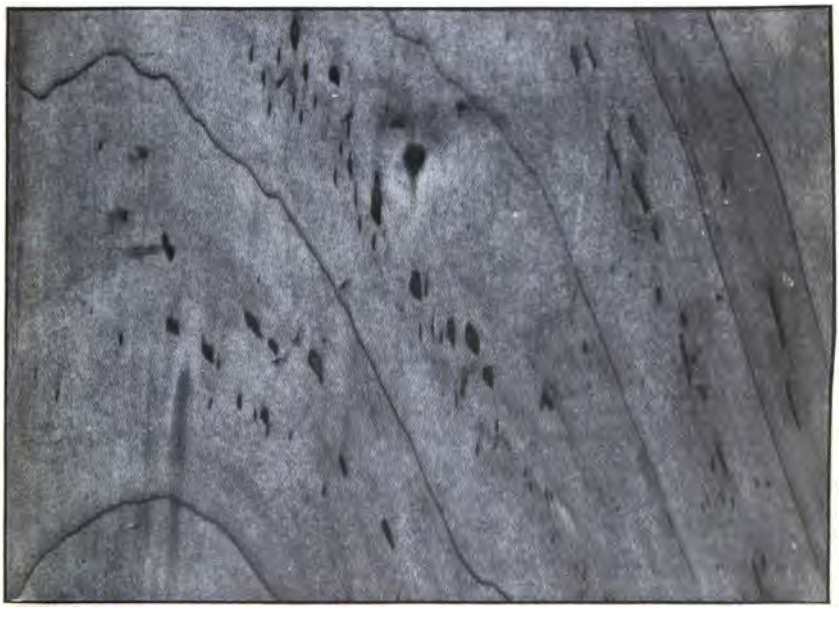


FIG. 2.—TANGENTIAL SECTION OF THE TRUNK OF SILVER MAPLE, SHOWING PITH FLECKS. NATURAL SIZE.

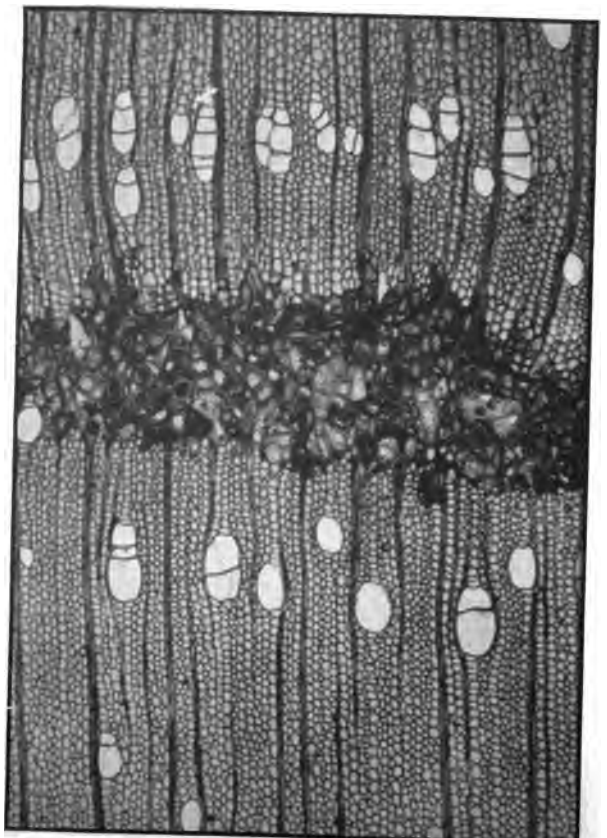


FIG. 1.—TRANSVERSE SECTION OF RIVER BIRCH, SHOWING PITH FLECKS. MAGNIFIED 60 DIAMETERS.

FIG. 2.—BARK OF RIVER BIRCH REMOVED, SHOWING DISTRIBUTION OF THE MINES OF LARVÆ.

FIG. 1.—TRANSVERSE SECTION OF WILD PLUM, SHOWING THREE PITH FLECKS. MAGNIFIED 30 DIAMETERS.

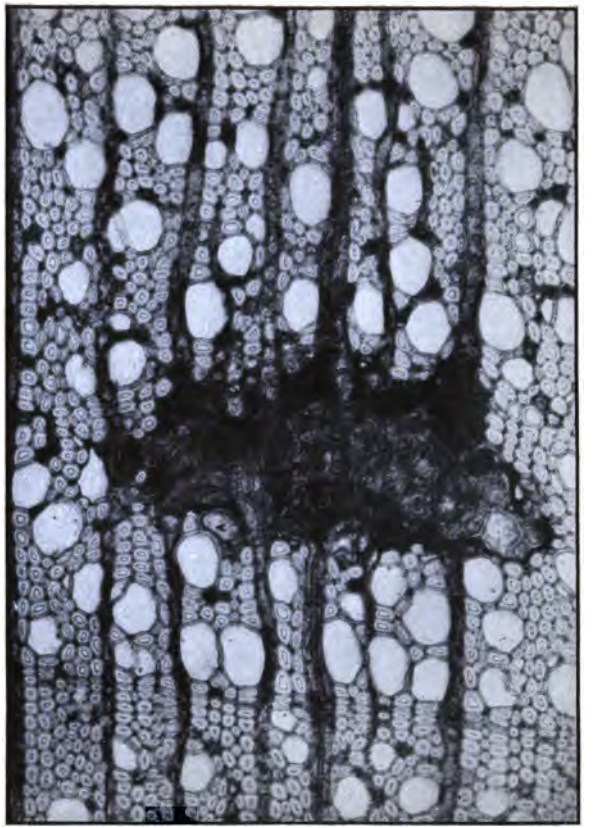
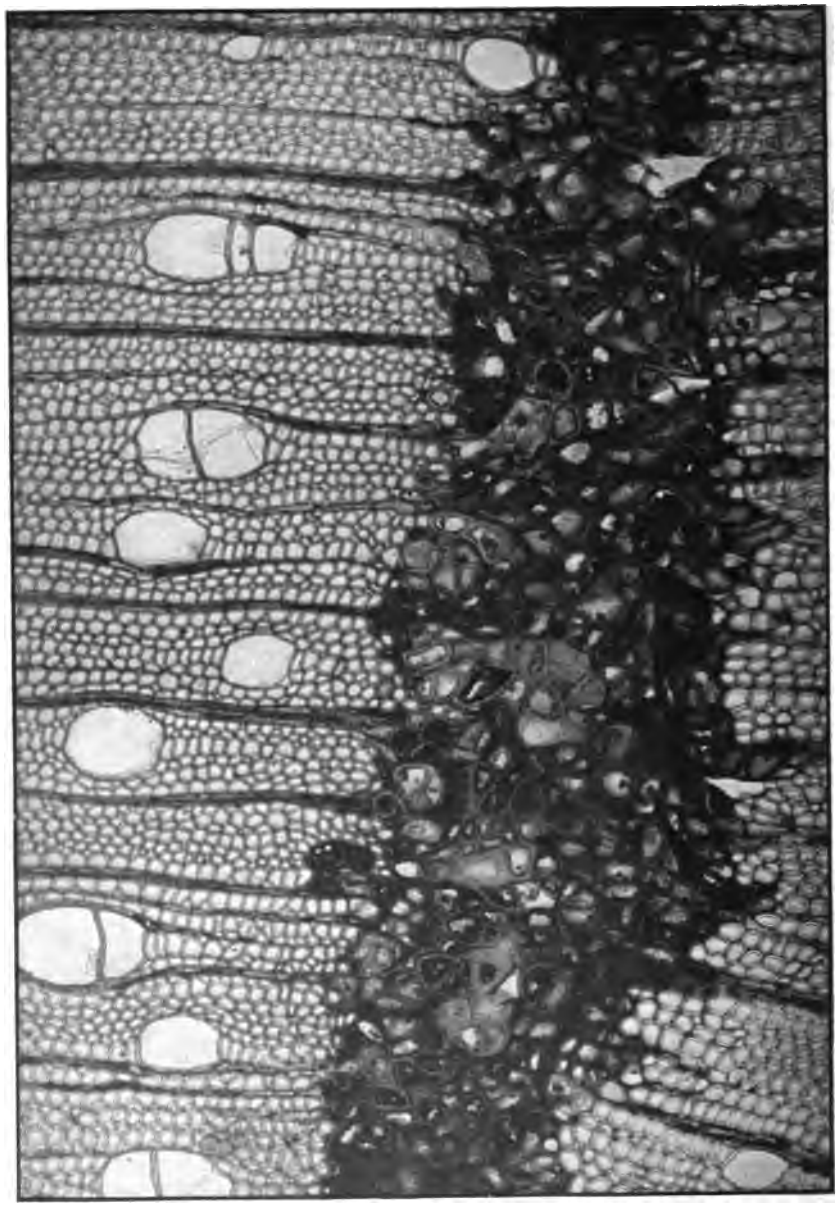


FIG. 2.—TRANSVERSE SECTION OF SERVICEBERRY, SHOWING ONE PITH FLECK. MAGNIFIED 120 DIAMETERS.



TRANSVERSE SECTION OF RIVER BIRCH THROUGH PITH FLECK, SHOWING CONNECTION BETWEEN WOUND TISSUE AND PITH RAYS. MAGNIFIED 150 DIAMETERS.

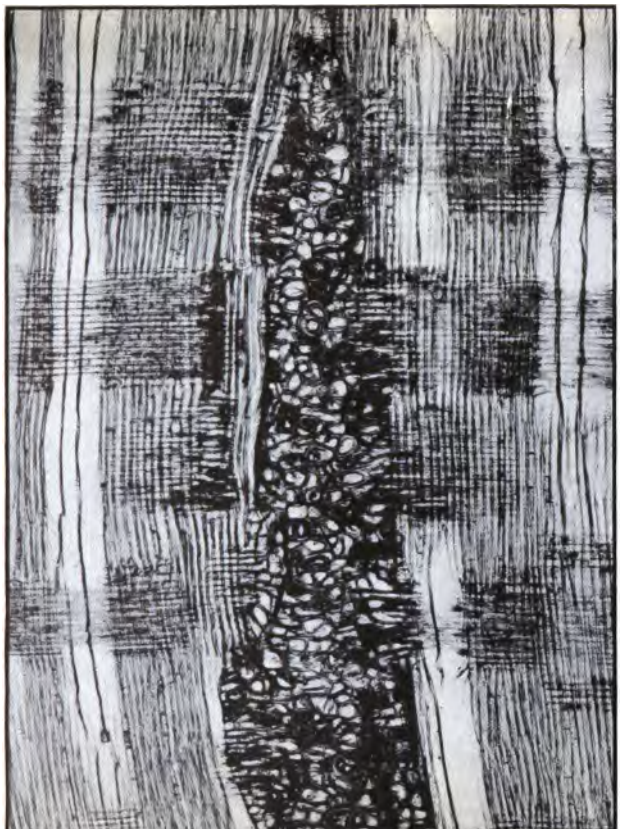


FIG. 1.—RADIAL SECTION OF RED MAPLE THROUGH A PITH FLECK, SHOWING CONNECTION WITH PITH RAY. MAGNIFIED 120 DIAMETERS.

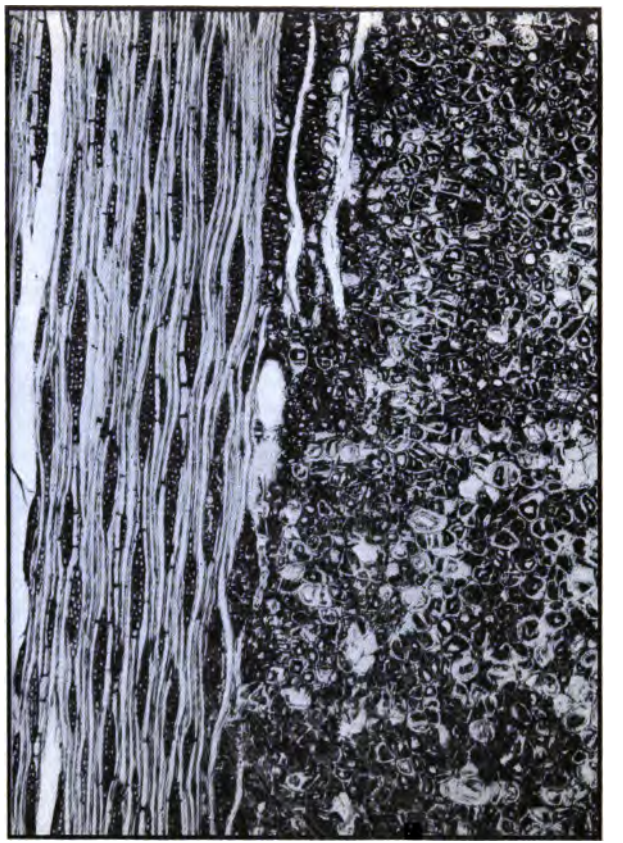
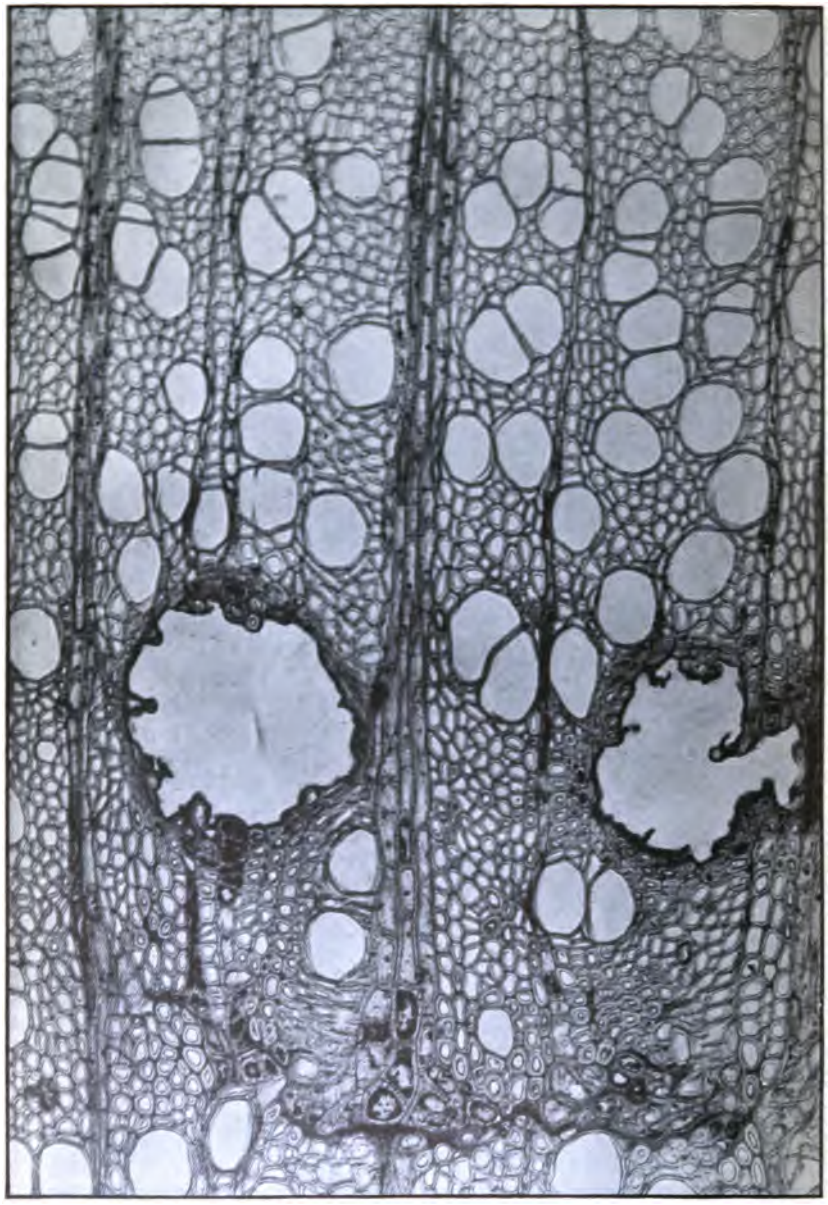


FIG. 2.—TANGENTIAL SECTION OF RIVER BIRCH THROUGH WOUND TISSUE OF PITH FLECK AT THE TOP. MAGNIFIED 120 DIAMETERS.



TRANSVERSE SECTION OF BLACK CHERRY, SHOWING TWO CAVITIES CAUSED BY GUMMATION OF WOUND TISSUE. MAGNIFIED 150 DIAMETERS.

long, as in river birch, the wound tissue consists of cells with correspondingly larger cavities. Division in this case takes place more tardily. Even under the stress of wound stimulus, the inherent character of cell formation persists. There seems, then, to be a definite relation between the ray cells and the cells of the wound tissue. The relation, however, of the vessels to wound tissue is more obscure. In woods with small vessels there is usually a corresponding reduction in the cells of the wound tissue; while in woods with large vessels the reverse is true. Though no logical reason can be given for such a relation, present observations confirm it.

When viewed in tangential (bastard) section, the passages appear as broad bands of wound tissue. All appearance of pith-ray formation is lost. The cells are commonly isodiametric and polygonal in form (Pl. V, fig. 2), resembling in some respects the cells of the pith or medulla. A radial view (Pl. V, fig. 1) presents no new characters. The wound tissue is not as extensive in this section, however, since the larva works only in the cambium.

GROUPS AND SPECIES OF TREES AFFECTED.

Pith flecks are present in a greater number of tree species than is generally supposed. Nordlinger reported them as occurring in 41 genera, included in 27 families. A critical examination of sections prepared by him increased the list of hosts still further. It is possible that the markings found are all the work of the larvæ of a dipterous insect, but only extensive observations can determine this. That they are all caused by cambium miners is, however, apparent. No other injury would heal in the manner described.

As far as determined by the present investigation, pith flecks occur in only 5 families of trees in the United States, namely, the Salicaceæ, Betulaceæ, Rosaceæ, Aceraceæ, and Tiliaceæ. The following is a tentative list of woods indigenous to the United States in which pith flecks were observed:

SALICACEÆ.

Common name.	Botanical name.
Bebb willow	*Salix bebbiana* Sargent.
Long leaf willow	*Salix fluviatilis* Nutt.
Hooker willow	*Salix hookeriana* Baratt.
Smooth leaf willow	*Salix lævigata* Bebb.
Black willow	*Salix nigra* Marsh.
Nuttal willow	*Salix nuttallii* Sargent.
Silky willow	*Salix sitchensis* Sans.
Narrowleaf cottonwood	*Populus angustifolia* James.
Balm of Gilead	*Populus balsamifera* Linn.
Cottonwood	*Populus deltoides* Marsh.
Largetooth aspen	*Populus grandidentata* Michx.
Aspen	*Populus tremuloides* Michx.
Black cottonwood	*Populus trichocarpa* Torr. & Gr.

BETULACEÆ.

Common name.	Botanical name.
River birch	*Betula nigra* Linn.
Paper birch	*Betula papyrifera* Marsh.
White birch	*Betula populifolia* Marsh.
Hornbeam	*Ostrya virginiana* (Mill.) Koch.
Lanceleaf alder	*Alnus acuminata* H. B. K.

ROSACEÆ.

Serviceberry	*Amelanchier canadensis* (Linn.) Medic.
Western serviceberry	*Amelanchier alnifolia* Nutt.
Mountain ash	*Pyrus americana* (Marsh.) de C.
Narrowleaf crab	*Pyrus angustifolia* Ait.
Wild apple	*Pyrus malus* Linn.
Oregon crab	*Pyrus rivularis* Dougl.
Elderleaf mountain ash	*Pyrus sambucifolia* Cham. & Schl.
Allegheny sloe	*Prunus allegheniensis* Porter.
Wild plum	*Prunus americana* Marsh.
Sweet cherry	*Prunus avium* Linn.
Sour cherry	*Prunus cerasus* Linn.
Western choke cherry	*Prunus demissa* (Nutt.) Walp.
Bitter cherry	*Prunus emarginata* (Dougl.) Walp.
Garden wild plum	*Prunus hortulana* Bailey.
Hollyleaf cherry	*Prunus ilicifolia* (Nutt.) Walp.
Wild red cherry	*Prunus pennsylvanica* Linn.
Black cherry	*Prunus serotina* Ehrh.
Choke cherry	*Prunus virginiana* Linn.
Summer haw	*Cratægus æstivalis* (Walt.) Torr. & Gr.
Dotted haw	*Cratægus punctata* Jacq.

ACERACEÆ.

Striped maple	*Acer pennsylvanicum* Linn.
Red maple	*Acer rubrum* Linn.
Silver maple	*Acer saccharinum* Linn.

TILIACEÆ.

Basswood	*Tilia americana* Linn.

GEOGRAPHIC DISTRIBUTION OF THE CAMBIUM MINER.

The geographic distribution of the cambium miner can not be definitely fixed at present, because of the uncertainty of the source of many of the wood samples examined and of the difference in susceptibility of the same host in different situations. Nordlinger's list of woods includes species that grow throughout a vast area, and shows that pith flecks occur in wood of all tropical and temperate regions. Many European species examined contained them. Further investigations of foreign woods will doubtless increase the number of host trees. From the list of indigenous trees given it is seen that the insect producing these flecks is quite generally distributed over the United States. The extent to which different genera and

different species of the same genus are affected varies. Wood specimens of red maple from Pennsylvania and from Florida were abundantly infested, while those of the western maples were comparatively free. No western species of *Cratægus* seem to be immune, but this conclusion can be established only by further investigation. The genus *Pyrus* leads in number of species affected. It does not follow, however, that trees of this genus form the favorite hosts. As already mentioned, river birch is most often infested in Maryland and Virginia. There appears to be a peculiar local susceptibility of certain species. White birch, for example, is quite commonly infested throughout the New England States, but near the southern limit of its range the wood is usually entirely free of mines. Its successor in range farther south, river birch, becomes the favorite host. It is probable that this peculiar distribution of the insect's work holds also for the willows and poplars.

FACTORS AFFECTING LOCAL DISTRIBUTION OF LARVÆ AND PASSAGES.

Topography has little to do with the local distribution of the larvæ. Trees growing on uplands were found to be infested fully as often as those at lower elevations. It is not at all probable that bark characteristics have anything to do with the likelihood of infestation, since the mines can be traced to the young bark, which in thickness and smoothness is much the same on all trees. Organic infiltrations in the cortex may cause immunity in certain hosts. Tannin, perhaps, accounts for the total absence of the mines in American oaks. Resin is doubtless a preservative. Kraus reported pith flecks in the firs, spruces, and cedars (*Juniperus*), but later writers contradict this. Penhallow notes the formation in some coniferous woods of traumatic resin canals, which might be easily mistaken for pith flecks in a cursory examination.

The distribution of pith flecks in individual trees is readily inferred from the life history of the larvæ. Samples of wood taken from near the transition point of root and stem in infested trees show the mines in the greatest abundance. This is due to the frequent trips by the larvæ back and forth prior to pupation. The number of mines decreases rapidly after the first 10 feet above the ground. Above that distance, in transverse section, there is usually only one pith-ray fleck per larva.

The adult evidently deposits its eggs in the younger branches of the tree's crown. The larva, upon hatching out, burrows straight downward until near the ground, then makes several turns, as previously described. In red maple and river birch mines were traced about 40 feet down the stem with only slight deflections, and without a turn before reaching the base of the tree. The tangential diameter

is at first very small and rarely over 5 mm. even in the roots. The majority of mines are well within the margin of annual rings of growth; they rarely border on the spring or autumn wood of other rings. The larva begins its wanderings some time after growth begins and stops before the end of the growing season.

Nordlinger states that in certain species the mines are always in close proximity to the pith. This doubtless was correlated with bark characteristics because certain hosts were attacked only during their early existence. The present investigation, however, indicates that pith flecks in the eastern American hosts at least occur throughout the whole transverse section of the basal log. A large specimen of river birch was examined on July 22. The age could not be accurately determined, but a conservative estimate would place it at about 110 years. Many mines were observed at the base of the tree in the last season's growth. Other trees ranging from 10 to 80 years were found to be infested with the larvæ. In at least one species, river birch, both the young and the old trees are frequently attacked.

TAXONOMIC VALUE OF PITH FLECKS.

Early writers on wood ascribed a taxonomic value to pith flecks and efforts were made to use them in separating genera and species. If the distribution in certain genera were constant, the importance of these markings would be readily apparent. Record has pointed out, however, that they are of no value in this connection. The present investigations confirm his observations and considerably enlarge the list of infested woods. Pith flecks are clearly of pathologic origin, and their distribution in genera, species, and individuals is extremely irregular and uncertain. Their presence or absence, therefore, can not be used to identify woods.[1]

DETERIORATIVE EFFECT ON QUALITY OF WOOD.

Among the important quality factors of wood are strength, elasticity, texture, and freedom from knots and discolorations. Any agent that adversely affects one of these qualities may decrease the commercial value of the wood. Pith flecks may mar the natural beauty of woods by causing discolorations. In some woods pith flecks cause definite areas of disintegration in which normal tissues become involved. Intercellular spaces or cavities may thus arise.

The discoloration due to the work of dipterous larvæ arises from two causes. In all native species (except the willows and poplars) marked with pith flecks (pp. 9 and 10) the cavities of the newly formed wound cells become filled with a dark-brown substance responding to tannin

[1] Logically, of course, no pathologic condition or other accident could have any taxonomic value.

reactions.[1] This color serves to differentiate sharply the wound tissue from the normal cells surrounding it and renders the closed mines conspicuous in transverse sections (Pl. III). This is true particularly of light-colored woods, such as birches and maples. In cherry, however, owing to the similar color of the wood, the mines are quite inconspicuous, provided other pathological changes described herein, do not occur.

In maple (Pl. I, fig. 2) and birch the mines stand out in tangential or radial sections as brown spots or lines of varying magnitude, which run in the direction of the fibers. This renders the wood inferior in quality and useless for the finer grades of cabinetwork. The defect is emphasized for woods finished in the natural color, since filling and varnishing renders the spots still more distinct. Pith flecks are, however, frequently seen in all the cheaper grades of furniture. In veneers the injury is a still greater factor. Badly infested cherry is often useless for this purpose.

Another cause of discoloration is the result of interference with the normal physiological activities of the tree [2] where the medullary rays are broken by mining larvæ. The wood adjoining the mine for varying distances toward the center darkens prematurely and changes into heartwood. These discolored areas rarely cover more than two annual rings of growth, but in some of the poplar woods they were observed to extend through as many as eight annual rings. In other wood the discoloration, as a rule, is comparatively slight, serving mainly to render the occluded mines more conspicuous and rarely extending beyond the growth of the season.

Disintegration of woody tissue due to pith flecks was observed only in the wood of cherry. In various species of this genus there is a breaking down or disintegration of the tissue, accompanied by the usual formation of "cherry gum." This process is technically known as "gummation."[3] The correlation of pith flecks with the disintegration or liquefaction of normal woody tissues was probably first noted by Wiegand in 1863. He found that in sweet cherry pith

[1] In willow and poplar wood the occluded mines are often quite inconspicuous, owing to a lack of coloring matter in the wound tissue.

[2] The medullary rays of the wood continue out through the growing layer into the inner bark. Here they are in direct communication with the sieve tubes of the bast, and serve to conduct food material elaborated in the leaves to the growing layer of the wood. They consist of comparatively thin-walled cells that form, with the wood parenchyma, the living portion of the xylem. The other wood elements lose their protoplasmic contents soon after their formation, after which they perform the function mainly of water and air conduction. The wood parenchyma, however, lives for a number of years intimately associated with the physiological activities of the tree.

[3] Many conflicting opinions are held regarding the origin of cherry gum. Mikosch considers it a pathological product which follows the wounding of the cambium, and asserts that its formation takes place within the inner portions of the cambial layer. Rant ascribes its formation to three factors: (*a*) new formation of tissue, (*b*) liquefaction, (*c*) activity of the dead cells as a wound stimulus through necrosis. The latter may result through physiological influences or through the traumatic working of foreign organisms, such as bacteria, fungi, or animals. Ruhland further infers that oxygen is necessary for the process, and that in wounds where air is excluded no gummation results.

flecks are the principal starting points in gummation. His observations have been confirmed by more recent investigations.

In the present studies of the wood of cherry some mines were found filled with wound tissue of the usual type, while in others gummation was well under way (Pl. VI). There was apparently no distinction in species or individuals as regards the formation of gum. All species of cherry subject to pith flecks are also susceptible to the breaking-down process. This can be expected from the results obtained by Mikosch and Rant.[1]

The discolored spots produced by gummation in cherry wood often render it unfit for the finer grades of furniture. This defect is often directly traceable to pith flecks. Where the mines remain occluded with normal wound tissue, little injury results, owing to the similar coloration of the surrounding wood with that of the wound tissue. It is with the inception of gummation that the injury really begins. The disintegration thus started often spreads until the sound tissue is affected.

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[1] As previously noted, the larvæ live in the cambial zone and destroy the growing or dividing cells by sucking their contents. The burrow thus formed by the larva is partially filled with the remnants of dead cell walls and excrement of larvæ. It is still open to doubt whether gummation begins immediately before the wound tissue forms or whether the latter first fills the mines and then breaks down. Mines were found which presented all stages of development. Some were completely filled with normal wound tissue; while in others disintegration had affected a part of the cells. In some instances no wound tissue was in evidence; here the mines in cross section appeared like openings in the otherwise normal tissue. It is difficult to say whether the gum in such instances arose from the liquefaction of the dead cell walls or, as is more probable, from the wound tissue formed subsequent to the passage of the larvæ. Either theory may be reconciled with the deductions of Mikosch and Rant.

Regarding Ruhland's theory concerning the necessity of oxygen in the process, little can be said. It perhaps accounts for the absence of gum formation in some of the mines. Where gummation does occur it can hardly be ascribed to atmospheric oxygen. It is highly improbable that the latter would penetrate the mine for any great distance, owing to the small opening at its inception and to the rapid formation of wound tissue after the passage of the larva.

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U. S. DEPARTMENT OF AGRICULTURE,
FOREST SERVICE—Circular 216.
HENRY S. GRAVES, Forester.

EFFECT OF FOREST FIRES ON STANDING HARDWOOD TIMBER.

331

BY

W. H. LONG,
Forest Pathologist, Bureau of Plant Industry.

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The aim of this leaflet is to point out some of the direct and immediate injurious effects of light fires in a forest. Even a light fire may and does injure in many ways both public and private timber, and causes an actual money loss which can be measured in dollars and cents. When the actual damage done by fires is realized, their prevention will be as much the duty of the citizen as it is now his duty to protect his home from burning.

The most noticeable effects of a fire are the killing of the young growth, the destruction of the layer of leaves and mulch on the ground which protects the soil from washing in times of heavy rains, and the fire scars left on the trees of all ages and sizes. It is the object of this leaflet to call attention especially to the damage to merchantable timber evidenced by these fire scars. Though the study upon which the circular is based was made in the Ozark Mountains of Arkansas, the results are applicable to other hardwood regions.

All settlers and lumbermen who have worked in the hardwood timber in the Ozarks know only too well what is meant by pin worms, bunch worms, flag worms, grub worms, soak, and butt rots, and how great is the loss of timber due to them. Damage by insects and rot was found in connection with practically every fire scar on the bases of the trees. The fire may have occurred 50 or 100 years ago, and all signs of it been hidden by later growth, but during the two or more years that it took the tree to heal over the scar, worms, and spores or germs which produce rot in trees, entered at this open wound on the butt, and, in the case of the rots, have been at work ever since, gradually destroying the timber in the trunk.

Any little pile of leaves and other trash, which winds and water may have left lodged against the base of a tree, will, when dry and set on fire, produce sufficient heat to cook and kill the living bark and sapwood for several square inches on the butt. The injury thus caused is apparently slight, but in reality the damage done may continue during the entire life of the tree, and may finally cause its death. It is mainly through such small fire scars that the worms and rots get into trees.

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The spores, or "seeds," of the tiny fungus plants which cause the rot fall on the dead spot or fire scar, sprout during damp weather and grow into the heartwood of the tree. Once in the heartwood, the little plants use part or all of the wood as food, and thus gradually destroy the sound timber, producing what is called rot, dote, or soak in the trunk of the tree. The small fire scar may, and usually does, heal over, so that in a few years no evidence of a fire or injury to the tree can be seen from the outside; but the rot continues to grow for years, slowly spreading outward, until it reaches the sapwood, and upward in the trunk, thus ruining the tree for most commercial purposes. Every time a tree is reached by a fire hot enough to kill a small area of the bark and sapwood an opportunity is given for more worms to enter and for another attack by the little plants which produce rot. Where trees are growing on steep slopes small piles of trash collect on the upper sides at the base. In such cases even a light fire, which ordinarily would not be able to injure the tree at all, burns this pile of trash and a fire scar is formed. On the sides of Pilot Mountain are dense stands of young oak saplings from 2 to 6 inches in diameter, every one of which has a fire scar on the upper side of its base, due to the burning of these piles of trash. This means that a large number of these saplings will grow into trees having butt rots and wormholes in the trunks. Similar conditions can be seen on nearly every mountainside in the Ozarks.

Anyone in passing through a stave sale area after all the good bolts have been removed has noticed the large amount of cull left on the ground. Sometimes entire trees have not yielded a single bolt. What was the matter? Worms, rot, or soak had ruined the tree for staves. Cull butts from 6 to 16 feet in length are not uncommon on many areas where the timber has been felled. In nearly every case these butts were left on account of rot. Practically all of this was caused by fires which injured the bases of the trees.

The loss of good merchantable timber in a stave operation from rot and worms alone is enormous. Yet it is often said that light fires do not injure the forest, and some even claim that it is a benefit to burn the forests annually. On one stave sale area in the Ozarks 76 trees out of every 100 felled had butt rot, and 27 trees in every 100 had wormholes of some kind in them. What does this mean? It means that after going to the expense of felling 100 trees only 24 of them were perfectly sound and suitable for staves. Not only was there a money loss from the cull of 76 trees, but the expense of felling unsound trees must be considered. For five widely separated areas in the eastern part of this forest an average of 65 trees in every 100 had butt rot, and 26 had wormholes sufficient to cull some of the bolts.

Most of this loss can be traced directly to the fires so common in this forest. The area where 76 trees in every 100 were found to have butt rot has been burned over regularly for years. Over areas where fires had not been so frequent, the injury from butt rots was correspondingly less. The loss of timber in stave operations from worms and rots alone will often average one-fourth of the total amount of material actually used for staves. It is for this very reason that stave men in buying private timber offer such low prices; they do not know till the timber is felled and worked up just how much loss there will be from worms, soak, and rot; they do know, however, that the loss will be great. The loss from worms and rot caused by forest fires is not confined to white oak, but extends to red and black oaks as well. Old fire scars on the butts of these trees are the usual places where many wood-boring insects enter the tree. On some areas as many as 33 trees out of every 100 red and black oaks felled had been injured by grubworms. The usual butt rots of white oak are also found in the other oaks, and fire scars are the places through which they enter.

Another way that fires injure standing timber is by burning through sound bark and sapwood into the hollow butts. Once the hollowed-out interior of the tree is exposed to the air, the rot which originally caused the hollow seems to grow up the tree more rapidly, while other fires that follow gradually widen the hollow and destroy the bark at the base of the tree until the tree is killed.

A tree which has an open, hollow butt is much more easily blown down than one in which the hollow is inclosed by living bark and sapwood.

We find, then, that forest fires damage standing timber in three ways: By producing fire scars through which worms enter, by opening a passage through the bark and sapwood for rots to reach the heartwood, and by weakening trees with hollow butts till they either burn down, die from fire girdling, or are blown over by strong winds. Every fire, therefore, only increases the damage by making possible a new crop of worms in the trees and by giving another chance for rots to enter through the new fire scars, thus increasing the quantity of unmerchantable material and decreasing the amount of money received for the timber.

This deterioration in the standing timber is the direct source of a tremendous loss to the entire community, for no one will buy worthless timber. The timber itself is not only a total loss to the settlers and other owners, but by its presence it also increases the cost of lumbering and decreases the stumpage value of what timber is merchantable. Furthermore it means a loss in wages to the laborer, and a loss to the State of the 35 per cent of all receipts from the sale of

Government timber appropriated by Congress for the construction of public roads and for the maintenance of schools within the State.

The conclusion, then, is obvious, that the continued burning of timbered lands in Arkansas is causing an annual loss of thousands of dollars—an absolute detriment to the welfare of the State. And it is equally obvious that this loss can be almost entirely eliminated by the prevention of all forest fires, whether large or small—a comparatively easy matter if all the people will only cooperate in the work.

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